VOLUME XXXVII NUMBER 3

BOTANICAL GAZETTE

MARCH, 1904

THE LIFE HISTORY OF RICCIOCARPUS NATANS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LIV.

JOHN F. GARBER.

(WITH FOUR FIGURES AND PLATES IX AND X)

THE beginning of the exact knowledge of the morphology of the Hepaticae dates from Hofmeister (1), who in 1850–62 published important investigations upon this group. Having discovered the egg cell in the archegonium, he traced the sperm to the surface of the egg and thus showed that the egg is fertilized by the sperm. He had previously announced his conclusion that the ordinary vegetative plants of mosses are the morphological equivalents of the prothallia of ferns, and that in mosses as well as in ferns there is a true alternation of generations.

Kny (2) gives a résumé of the literature on the morphology of Hepaticae up to 1867. He detected the apical cells and their method of segmentation in building up the thallus. He also described some stages in the development of the sex organs, and discovered the origin and manner of growth of the ventral scales. The thallus to him represented a fusion of stem and leaf.

Strasburger (3) mentions and figures the canal cells, but saw no walls separating them. He does not mention the ventral canal cell as different from the others, though one of his figures clearly shows it.

Leitgeb (6) in 1874–82 published comparative studies of the entire group of Hepaticae. In the Ricciaceae and Marchantiaceae he described the structure of the thallus and its method of

growth, the formation of air chambers and pores, and showed that the ventral scales are homologous with the walls separating the air chambers. Corda had previously suggested the separation of *Ricciocarpus natans* from Riccia as an independent genus. Leitgeb, after examining Ricciocarpus, gives the following as distinguishing characters: (1) the constant presence of definitely formed air pores similar to those of Corsinia and Boschia; (2) numerous ventral scales which are formed independently and have long-continued basal growth; (3) a rudimentary integument (Hülle) around the sporogonium; (4) antheridia collected into groups similar to those of Marchantiaceae. Leitgeb lays stress on the grouping of sex organs, and suggests a progressive series in which the lowest member has the sex organs scattered indiscriminately over the upper surface and the highest has the definite group of sex organs terminating a branch.

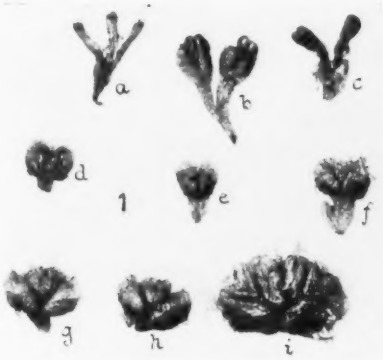
Fellner (**14**) studied the germination of the spore and the development of the thallus in *Riccia glauca*.

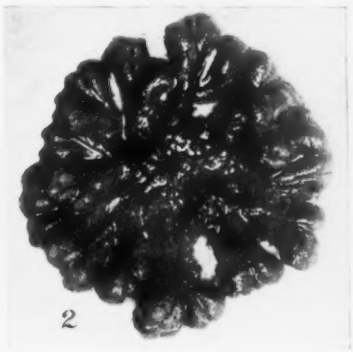
MATERIAL AND METHODS.

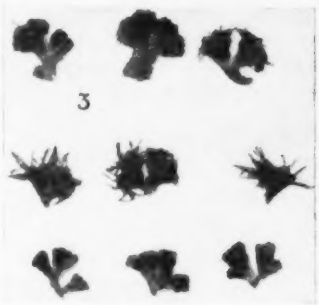
The material for the present study was collected during the spring and summer of 1902, and was fixed in a chrom-acetic acid mixture (1 per cent. of each) for twelve to twenty-four hours. After washing thoroughly in running water for a few hours, the plants were brought gradually into 70 per cent. alcohol. Pieces including an apex of a branch and a dorsal furrow were cut from these preserved plants. Since the loose, delicate tissues are very likely to collapse, the material should be hardened and dehydrated gradually, and the absolute alcohol should be renewed once or twice to insure perfect dehydration before any xylol is added. It is well to have xylol grades of 25, 50, and 75 per cent. in absolute alcohol, through which the material is passed with intervals of an hour between successive grades. After a short time in pure xylol, paraffin is added as fast as it is dissolved by the xylol. The paraffin should be changed three or four times during the three hours in the bath, after which the material may be imbedded. Sections perpendicular to the flat surface of the thallus and also to the median furrow are best for

all purposes except to show a series of stages in a single section, in which case the sections should be parallel to the furrow.

Delafield's haematoxylin or Heidenhain's iron-alum haematoxylin proved excellent for young stages of the sex organs, and the latter stain was especially good for older stages of the sporophyte. Flemming's safranin gentian violet combination was most satisfactory for nearly mature archegonia and the process of fertilization.







Ricciocarpus natans.

FIG. 1.—*a* and *c*, plants injured by insects, the apical cells growing independent branches; *b*, single branch of soil plant like *fig. 2*; *d–i*, successive stages in the growth of fruiting plants.

FIG. 2.—A rosette growing on the soil.

FIG. 3.—Vegetative water plants in autumn.

THE THALLUS.

The common floating form of Ricciocarpus is so familiar, and has been so well described by Bischoff (**13**) and others, that no further description of external appearance seems necessary. A series of stages in the development of the floating form is shown in *fig. 1* (*d–i*).

The upper surface of the plant is divided into small areas as in Marchantia, and in the center of each of these areas Leitgeb discovered a simple air pore surrounded by about six guard cells (*figs. 10, 11*). Two or three tiers of air chambers compose the green tissue, the walls and roofs of the chamber being composed of chlorophyllose cells. The storage tissue, composed of about ten layers of colorless, starch-filled cells, forms a strip beneath each dorsal furrow. The method of growth of the

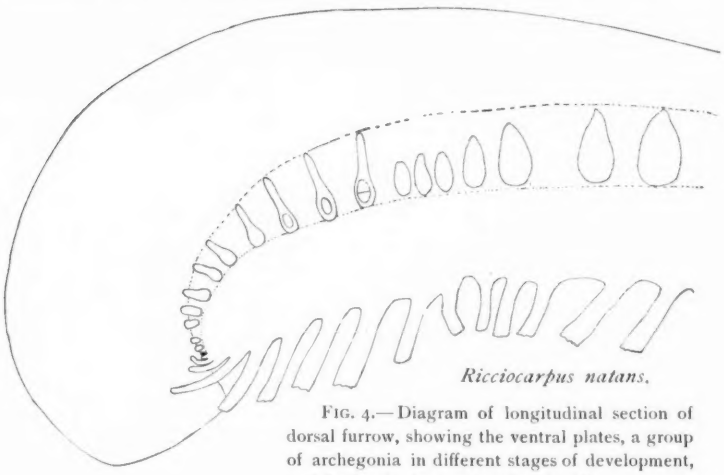


FIG. 4.—Diagram of longitudinal section of dorsal furrow, showing the ventral plates, a group of archegonia in different stages of development, and further back a group of antheridia.

thallus and the formation of air chambers, air pores, and ventral scales has been so thoroughly worked out by Leitgeb (**6**) that there is little to add to his account. The number of apical cells at the anterior end of each furrow is larger than he supposed, averaging about five in our plants, as may be seen from the number of rudiments of ventral scales in a nearly horizontal section taken just below the apex (*fig. 9*). The position of the apical cells and their relation to the ventral scales is made clear by the sections represented in *figs. 4, 7, 8, 9*.

The dorsal furrow in cross section has somewhat the form of an inverted Y, with a more or less prominent median longitudinal ridge between the arms. Early observers supposed this ridge to

be produced by the enlarging of the sporophyte, but it occurs independently of this and is not present in purely vegetative plants. As growth proceeds, the plants become broader and thicker, and at the same time the older posterior parts decay (*fig. 1*). The decay sets free the ripened spores and provides for vegetative multiplication by separating the branches. No vegetative multiplication occurs during the spore-producing season.

THE SEX ORGANS.

It is a common statement that Ricciocarpus fruits only when in contact with the soil. In this vicinity no stranded fruiting plants have ever been collected except such as showed clearly that the fruiting process was already far advanced before the plant came to rest. A careful examination of abundant material in numerous localities shows that the fruiting plants normally float free on the surface of the water from germination of the spores until the spores of the next generation are ripened and discharged. The untimely withdrawal of the water often leaves mature plants stranded, and although they develop rhizoids very quickly, no change of form occurs until the spores have been discharged.

Ricciocarpus is described by Schiffner, Leitgeb, and Campbell as being strictly dioecious. Our investigations prove conclusively that it is strictly monoecious. The error of previous observers doubtless arose from the exclusive examination of mature plants, which normally bear only sporophytes because the antheridia have been lost by the decay of the older portions of the thallus. A very few plants usually produce antheridia only, and retain these until the plants are full grown, while still other plants may be quite sterile. Young plants and those formed from broken-off floating tips of soil plants very soon begin to produce antheridia in from three to five rows. The antheridia are at first superficial on the floor of the dorsal furrow just behind the apical cells. They gradually become sunken in cavities by the upgrowth of the vegetative tissue surrounding them (*figs. 4, 5*). The series may be interrupted at intervals so that the antheridia may occur in more or less definite groups,

and late in the season on plants that fail to produce sporophytes these groups may be inclosed in definite common integuments terminating above in a sort of beak. It was this kind of a group on which Leitgeb (**6**) based his classification. The plants marked *d* and *e* in *fig. 1* have completed the series of antheridia and, if growth should continue, at once there would begin a series of from three to five rows of archegonia in position and arrangement a continuation of the antheridial rows (*figs. 4, 6*). The archegonial series is complete in a plant like *h* (*fig. 1*), from which the diagram (*fig. 4*) was made.

The cavities inclosing the sex organs are morphologically air chambers. The organ is graduated in length to the depth of the cavity, so that its apex is always approximately on a level with the floor of the dorsal furrow (*figs. 5, 6*). It may be noted that most of the antheridia are found in the narrower and less fleshy portions of the plants, while the archegonia are located in the more vigorous portions. The antheridial portions of the plant are produced early in the season, when conditions for growth are comparatively unfavorable. In this it reminds one of the prothallium of a polypod fern, which while young and delicate or in unfavorable conditions produces only antheridia, but if circumstances become more favorable, the enlarging, more vigorous plant begins the production of archegonia. Antheridia are produced during April, and by May 1 the youngest ones are half developed, the oldest having already discharged their sperms. The mature organ is a short-stalked, oval body, conical at the apex, with a wall consisting of a single layer of cells. Though antheridia are produced earlier in point of time than archegonia, their development is so much slower that both are mature at the same time. The sperms are of the usual biciliate type and have two complete coils.

A complete series of stages in the development of the archegonium was found on plants collected May 1. The course of development is the same as that outlined by Janczewski (**11**) for the typical liverwort archegonium. In the outer cell of the archegonium rudiment three successive vertical walls inclose a triangular cell which shortly divides by a transverse wall (*fig. 15*)

into an upper cover cell, and a central cell which is to give rise to the axial row. This latter division is quickly followed by divisions in the outer wall cells, when the archegonium is composed of two tiers of four cells each. Successive divisions in the outer cells lengthen the neck and enlarge the venter.

The upper of the first two cells of the central row by two successive divisions produces regularly four neck canal cells, the same number as that reported for the species of Riccia which have been studied. The lower of the first two cells enlarges very rapidly and shortly before fertilization divides, giving rise to a small ventral canal cell and the egg cell (*figs. 20–22*). The egg fills the entire venter of the archegonium, except the small portion occupied by the ventral canal cell. Its protoplasm is at first somewhat vacuolate, but it rapidly becomes denser by the increase of food materials. Starch grains inclosed in plastids are so numerous at the time of fertilization as to be conspicuous even with moderate magnification. The surface of the egg next to the ventral canal cell is concave, and this condition disappears only with the resorption of the ventral canal cell, when the egg assumes a nearly spherical or a somewhat oval shape. The breaking down and resorption of the ventral canal cell seem to be dependent upon the entrance of the sperm, for the degenerate ventral canal cell is still to be recognized in archegonia that have failed to be fertilized, and in which the egg is rapidly shrinking and approaching complete disorganization, as in *fig. 26*.

The basal cell is larger than the outer one which forms the archegonium proper (*figs. 12, 13*). Two vertical walls very early divide it into four cells (*figs. 14–16*). Later divisions in various directions form a prominent mass of cells imbedded, with the exception of the short stalk, in the storage tissue beneath (*fig. 39*). This mass of cells appears to digest the abundant starch of the storage cells, so that it may be readily transferred to the growing sporophyte. The appearance and position of this tissue in relation to the storage mass indicates that it is the physiological equivalent of the foot of the sporophyte in higher forms.

Campbell (**7**) states for Riccia in general that the basal cell

divides but a few times, forming the short stalk. For *Riccia hirta* in particular he says that "the basal cell finally divides into a single lower cell which remains undivided, completely sunk in the thallus, and an upper cell which divides into a single layer of cells forming part of the venter." For Targionia the same author says that "the basal cell undergoes irregular divisions and its limits are soon lost." Strasburger figures and describes the basal cell in *Marchantia polymorpha* as almost or quite superficial, forming only the stalk.

The arched ring of cells surrounding the opening through which the archegonium neck protrudes at the bottom of the dorsal furrow, regarded by Leitgeb as a rudimentary integument, appears to be merely the guard cells of the air pore belonging to the cavity in which the archegonium grows.

FERTILIZATION.

Soon after the ventral canal cell is cut off, the neck canal cells break down and the resulting mass extrudes from the tip of the neck between the separated cover cells at the bottom of the furrow. The pressure being removed from above, the cytoplasm of the egg may withdraw slightly from the venter walls and round off somewhat, the upper surface always remaining concave. The egg fills about three-fourths of the venter cavity. The shrinkage is not nearly so much in the healthy egg of Ricciocarpus as is figured in texts for Riccia, only degenerate archegonia having eggs so much shrunken (*fig. 26*). Sperms swim to the archegonium through the small quantity of water held in the furrow, which acts as a capillary tube whose ends dip to the water level. Numerous sperms were observed entangled in the mass extruded from the neck of the archegonium. The male and female nuclei were seen in various stages of fusion near the center of the egg (*figs. 23–25*). The diameter of the male nucleus is about one-half that of the female nucleus, and at the time of fusion stains darker because the chromatin elements are crowded more closely together. The male nucleus presses in the side of the membrane of the female nucleus until almost completely imbedded.

So far as I know, the observation of the phenomena of fertilization in a liverwort has been recorded only for Riella, studied by Kruch (9). He was, however, unable to get stages of actual fusion of the nuclei. With the entrance of the sperm, marked changes begin both in the egg and in the surrounding tissues. The oospore develops a cellulose membrane and quickly enlarges so as to fill completely the cavity of the venter. The cells of the venter begin dividing by walls parallel to the surface and make a complete double layer before the first division of the fertilized egg. A two-layered calyptra seems to be the rule among Ricciaceae, but as many as four layers occur among the Marchantiaceae.

THE SPOROPHYTE.

The first division in the sporophyte is usually transverse (*fig. 27*), but it may be oblique (*fig. 28*). The next wall may appear first in either the epibasal or hypobasal cell, and may be perpendicular to the first wall, thus forming a quadrant, or may be parallel to it, producing a row of four cells (*fig. 30*). Divisions then occur in all directions, producing a mass of thirty or forty cells, after which the amphithecium becomes distinguishable as a regular layer enclosing the spore-producing cells. Further divisions, not simultaneous (*fig. 32*), produce approximately four hundred spore mother-cells.

Up to this point the sporophyte has been a solid mass. Now the calyptra and amphithecium expand, leaving the spore mother-cells free, rounded, and separated from one another. At the same time there is excreted from the surrounding tissues a large quantity of nutritive material which fills the spaces around the mother-cells, giving them the most favorable conditions for rapid growth. Most of this nutritive material is absorbed by the spore mother-cells as they rapidly enlarge to fill again the amphithecium, and the remainder is pressed into thin plates adhering to the surface of the tetrads of spores (*fig. 38*).

The inner layer of the calyptra collapses shortly after the formation of the tetrads. The outer layer persists, while the amphithecium is distinguishable until the spores are almost ripe. All of the spore mother-cells produce spores, with no

indication of elaters or sporophyte foot of any kind. Thus, as in Riccia, Ricciocarpus presents the simplest of hepatic sporophytes, which fact, I think, should be associated with a strictly aquatic habitat. To my knowledge, all floating liverworts have this simple form of sporophyte, while nearly all of those normally living and fruiting on the soil (including the submerged Riella) have to some degree developed sterile structures in addition to the simple capsule wall. The soil contact rationally appears to be a necessary stimulus to any extensive sterilization of sporogenous tissue in the progressive manner contemplated by Bower (**15**), because only on the soil does it seem possible so to establish an independent sporophyte.

A summary of the fruiting period about Chicago in 1902 is approximately as follows:

April 10–20. Formation and development of antheridia.
April 20—May 5. Formation and development of archegonia.
April 25—May 5. Fertilization.
April 25—June 20. Growth of sporophyte, production and shedding of spores.

Any given sporophyte matures in about three weeks from the time of fertilization, and when mature exceeds the volume of the egg from which it is derived about five hundred times. In the structure of its thallus Ricciocarpus is much more complicated than any Riccia. But the most important points in classification are connected with the arrangement of the sex organs on the thallus and the structure of the sporophyte. In the lowest species of Riccia the sex organs are scattered indiscriminately over the surface, while in *Riccia fluitans* there is said to be a regular alternation of single antheridia and archegonia. Leitgeb based his classification of the plant on old, isolated, exceptional groups of antheridia. The antheridia should be considered as being produced in a definite region of the plant in one large group, which is followed by the production of a similar group of archegonia. These groups may be compared to the arrangement found in Asterella, Sauteria, etc., and mark the farthest advance made by Ricciocarpus. On the basis of its complicated thallus and definitely limited regions of sex organs, I should place Ric-

ciocarpus, as did Leitgeb, intermediate between Riccia and Marchantia, but with a distinct difference in conception of the arrangement of sex organs. He supposed the antheridia to be in several small groups and the archegonia to be scattered along the furrow with no attempt at grouping. All of his small groups of antheridia really belong together in one large group. The archegonia are also produced in a single region and should be regarded as a definite group.

A series of increasing concentration of sex organs into groups in specialized regions of the plant may be traced up to Marchantiaceae. Beginning with the lowest species of Riccia, sex organs are indiscriminately scattered. In *Riccia fluitans* there occurs a regular alternation of single sex organs. Ricciocarpus produces first all antheridia in a group and then all archegonia in a similar group, but with less apparent specialization of the areas bearing them than occurs in Targionia, which has the groups in special pits, and Corsinia which bears them on elevations.

On the other hand, the simple sporophyte, together with the feeding tissue derived from the basal cell of the archegonium, indicates primitive conditions not far removed from the simple sporophyte of Coleochaete.

Counts of chromosomes gave four for the gametophyte and eight for the sporophyte (*figs. 21, 35*). Kruch (**9**) gives eight and sixteen for Riella, and the same numbers are given by Farmer (**5**) and others for Pellia. The sporophyte spindle has very prominent and beautiful asters, but no centrosomes could be distinguished. The asters are identical with those of Pellia as described by Farmer (**5**), Davis (**8**), and Chamberlain (**16**), but no attempt was made to study their development.

BIOLOGY.

For biological data recourse was had to three sources, namely (1) the records of past collections, (2) the careful observation of various patches during one full season, and (3) experimentation in the laboratory.

The records of collections furnish facts as to dates and localities of fruiting in former years. With these data and by personal observation it was learned that in certain localities Ricciocarpus

reproduces sexually every year at approximately the same season, while in other localities it is to be found continually, but never reproducing sexually. The chief factor which brings about this difference seems to be the relative permanency of the water, spores being produced on temporary ponds and no spores on permanent ones.

The heavy-walled resting spore is suited to endure unfavorable conditions. When the water withdraws, the spores are left on the mud or even on dry soil, a condition which may be a necessary preparation for germination. The spores germinate early in the spring of the year following their maturity, that is, nearly a year after they have been shed. The water may remain long enough after the fruiting season for a period of vegetative multiplication to intervene, and thus many plants may be left to grow on the mud. If the mud remains very wet, there are produced beautiful rosettes like *fig. 2*, formed of numerous slender branches that remain connected at the center of the rosette.

As a rule, there seems to be little chance of survival for the stranded plants. From the under surface there is put forth a dense mass of rhizoids which anchors the plant firmly to the soil. Soil contact causes the older ventral plates to wither, but new ones continue to be produced at the apex in the usual way, though they cannot become prominent because the rhizoids pull the plant down close to the soil. If the water should return, these plants would be submerged, and, unable to float to the surface, would very likely perish, as most of the plants growing on the soil probably do. In special cases, however, the land plants have been able to endure the submergence, until by decay of the older portions the young tips of the branches are set free, when they rise to the surface and develop into the floating form again. By taking large healthy branches from the soil and placing them in water, it was found that only the extreme tip remains slightly above the water surface. The remainder extends vertically into the water and soon decays, while the young tip develops the usual floating form of the plant.

If the body of water is permanent, the surface may be covered with small plants that multiply vegetatively throughout the season,

so that countless numbers may extend over acres of water surface when the pond freezes. Large numbers of these plants probably die, but many of them, as the light and heat diminish, gradually become accustomed to submergence. The cold weather finally causes the plants to become black and apparently dead, in which condition they may float, become partially submerged, or even sink to the bottom. In this hibernating condition the plants have been taken from beneath the ice in early spring. When brought to the laboratory, the extreme apical region of each dorsal furrow grew out into a new plant. These new plants soon assume the vegetative water form and separate themselves from the old plant. Bischoff (**13**) mentions that *R. natans* lives over winter in a similar manner in Europe.

Rhizoids should be regarded as structures called forth by soil life, but in no sense as taking the place of ventral plates, which are always present.

The older parts of the plant possess no plasticity, but the meristematic region about the apical cell has a plasticity practically unlimited. If the plants are very much crowded, so that some are forced below the surface of the water, very commonly one or more of the apical cells will produce slender branches, which grow immediately to the surface. This is evidently an adaptation to get the plant into a favorable position again with the least possible expenditure of energy and tissue. A similar result occurred with some plants that were being kept in the laboratory. An insect ate out most of the vegetative tissues about the apex, and the restraining pressure being removed from them the apical cells grew out into independent branches (*fig. 1, a, c*). The great plasticity of the apical region in Ricciocarpus gives it the possibilities that one would expect to find in a transition form from aquatic to terrestrial liverworts. The gametophyte on the soil has the essential characteristics of terrestrial forms like Marchantia, except that it has not yet acquired the power to produce sexually there. If Ricciocarpus should acquire the power to produce sexually while on the land, it would become independent of the water.

A fungus belonging to the Ustilagineae frequently attacks the

young sporophytes, completely destroying them and filling the venter of the archegonium with a dense mass of the smut spores. These spores are so much smaller and so much more numerous than the Ricciocarpus spores that the infected sporophytes are recognized at a glance. Although the fungus enters the archegonium soon after fertilization, the young sporophyte continues to grow, apparently following the normal course of development up to the spore mother-cell stage, and even to the formation of spores. By this time, however, the mycelium and numerous spores of the fungus are tightly packed about the Ricciocarpus spores, which soon break down and are destroyed by the encroaching fungus (*fig. 40.*)

The life history of the fungi inhabiting various liverworts was carefully followed by Cavers (**10**). He states that the fungal hyphae usually grow down the neck of the fertilized archegonium, but they may pierce the venter and thus enter the sporogonium directly. In all cases where the sporogonium is invaded the relation of host plant and fungus is regarded as pure parasitism. Where the fungus penetrates only gametophyte tissue it may form a mycorhiza, the host plant living as a saprophyte, the relation of fungus and host being apparently that of symbiosis.

I am under obligations to Professor J. M. Coulter and Dr. C. J. Chamberlain for suggestions and advice during this study.

SUMMARY.

1. When fruiting, Ricciocarpus is essentially a free floating plant.

2. The genus is strictly monoecious, though a small number of plants fail to produce archegonia.

3. Sex organs are produced in single definite groups as in Asterella, etc. Antheridia are produced on very young plants, which later produce archegonia and sporophytes.

4. The basal cell of the archegonium develops a structure which is partially imbedded in the storage tissue and acts as the physiological equivalent of the sporophyte foot in higher forms.

5. There is no rudimentary integument of the archegonium.

6. The diameter of the male nucleus is about one-half that of the female nucleus.

7. The first division of the sporophyte is transverse or oblique. The early subsequent divisions are irregular.

8. A large quantity of nutritive material is excreted into the capsule among the mother-cells.

9. There is no indication of elaters or sporophyte foot of any kind, which fact is associated with the aquatic habitat.

10. The fruiting period occurs in spring and occupies about ten weeks.

11. The gametophyte number of chromosomes is four, the sporophyte number eight.

12. Permanency of the water appears to be unfavorable to sexual reproduction.

13. Plants once established on the soil are usually unable to resume the floating condition, but under exceptional circumtances they may do so.

14. Vegetative plants hibernate at the bottom of the pond, producing new plants the following spring.

15. Rhizoids do not replace ventral plates, but are an addition to adapt the plant to a life on the soil.

16. The apical region is exceedingly plastic.

17. The sporophytes are frequently invaded and destroyed by a fungus belonging to the Ustilagineae.

LITERATURE CITED.

1. HOFMEISTER, WILHELM, On the higher Cryptogamia. Ray Society. 1862.

2. KNY, L., Ueber Bau und Entwickelung der Riccien. Jahrb. Wiss. Bot. **5**: 364–386. *pls. 44–46.* 1867.

3. STRASBURGER, E., Die Geschlechtsorgane und die Befruchting bei *Marchantia polymorpha.* Jahrb. Wiss. Bot. **7**: 409–422. *pls. 27–28.* 1869.

4. FARMER, J. B., Studies in Hepaticae. Annals of Botany **8**: 35–52. *pls. 6–7.* 1894.

5. FARMER, J. B., and REEVES, JESSE, On the occurrence of centrospheres in *Pellia epiphylla* Nees. Annals of Botany **8**: 219–224. *pl. 14.* 1894.

6. LEITGEB, H., Untersuchungen über die Lebermoose **4**: 1879.

7. CAMPBELL, D. H., Mosses and Ferns. 1895.

8. DAVIS, B. M., Nuclear studies in Pellia. Annals of Botany **15**: 147–180. *pls. 10–11.* 1901.

9. KRUCH, O., Appunti sullo sviluppo degli organi sessuali e sulla fecondazione della *Riella Clausonis* Let. Malpighia **4**: 403–423. *pls. 17, 18.* 1890.

10. CAVERS, F., On saprophytism and mycorhiza in Hepaticae. New Phytologist **2**: 30–35. 1903.

11. JANCZEWSKI, EDUARD v., Vergleichende Untersuchungen über die Entwickelungsgeschichte des Archegoniums. Bot. Zeit. **30**: 377–393, 401–417, 440–443. 1872.

12. SCHIFFNER, V., Hepaticae. Die natürlichen Pflanzenfamilien. 1893.

13. BISCHOFF, Lehrbuch der Botanik. 1855.

14. FELLNER, FERD., Uber die Keimung der Sporen von *Riccia glauca*. Jahresb. Akad. naturwiss. Vereins in Graz. 1875.

15. BOWER, F. O., A theory of the strobilus in archegoniate plants. Annals of Botany **7**: 343–365. 1894.

16. CHAMBERLAIN, C. J., Mitosis in Pellia. BOT. GAZ. **35**: 28–51. *pls. 12–14*. 1903.

EXPLANATION OF PLATES IX AND X.

The magnifications are as follows: *figs. 10* and *11*, × 600; *fig. 20*, × 1600; *figs. 21* and *35*, × *ca.* 2500; *fig. 36*, × 850; all others, × 1000. In reproduction the drawings are reduced one-half.

FIG. 5. Diagram of cross section of dorsal furrow passing through a group of nearly mature antheridia.

FIG. 6. Diagram of cross section through group of archegonia; dotted lines indicate the limits of the starch-bearing tissue.

FIG. 7. Longitudinal section through the apex of a plant.

FIG. 8. Cross section through apical cell region.

FIG. 9. Horizontal section just below the apical cells with five rudiments of ventral scales.

FIGS. 10–11. Stages in the development of the archegonium before ventral canal cell is cut off; showing also development of tissue from basal cell.

FIGS. 20–21. Cutting off ventral canal cell.

FIG. 22. Archegonium nearly ready for fertilization.

FIG. 23. Fertilization; nuclei in contact, the male nearer to the eye in the section; egg with concave apex.

FIG. 24. Fertilization; starch grains in the plastids large and prominent.

FIG. 25. Fertilization further advanced; the male nucleus almost completely imbedded in the female nucleus, and the egg swollen out to fill compactly the venter.

FIG. 26. An unfertilized archegonium with egg and ventral canal cell degenerating.

FIG. 27. First division of the sporophyte by a transverse wall.

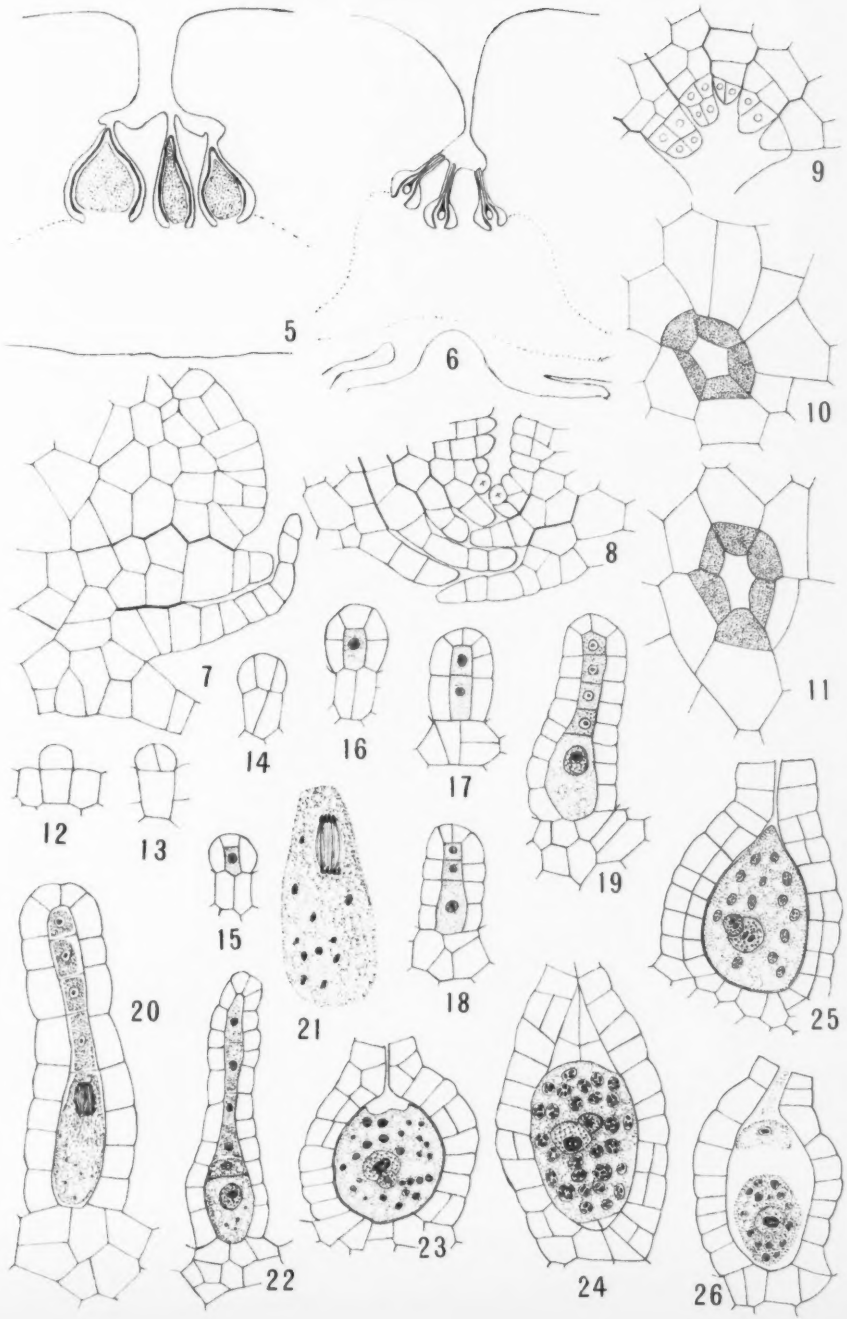
FIG. 28. First division of the sporophyte by an oblique wall.

FIG. 29. Four-celled embryo in form of quadrant.

FIG. 30. Four cells of embryo in a row.

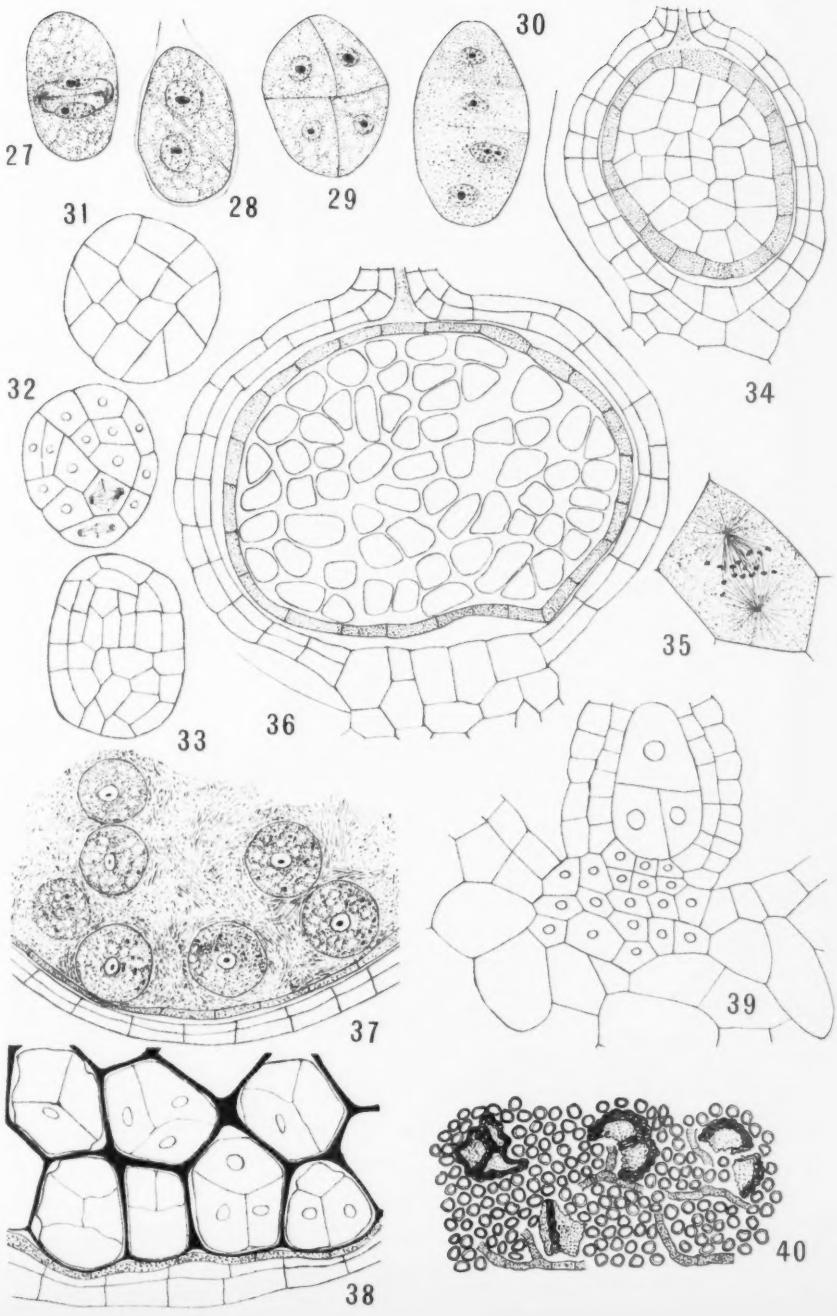
FIG. 31. Older embryo in which quadrant can still be distinguished.

FIG. 32. Embryo beginning to form amphithecium.



J. F. GARBER, DEL.

GARBER on RICCIOCARPUS.



J. F. GARBER, DEL.

GARBER on RICCIOCARPUS.

FIG. 33. Sporophyte with amphithecium almost complete.

FIG. 34. Sporophyte with amphithecium clearly differentiated.

FIG. 35. Sporophyte cell division; spindle has very prominent asters with eight chromosomes attached to each.

FIG. 36. Spore mother-cells free and rounding off.

FIG. 37. Spore mother-cells surrounded by nutritive material.

FIG. 38. Spore mother-cells forming tetrads surrounded by framework remaining from nutritive substance shown in *fig. 37*.

FIG. 39. Young sporophyte in an archegonium having a "foot" derived from basal cell imbedded in nutritive tissue of gametophyte.

FIG. 40. Diagram. Fungal hyphae and spores surrounding broken-down spores of Ricciocarpus.

VEGETATIVE CELL DIVISION IN ALLIUM.

MABEL L. MERRIMAN.

(WITH PLATES XI–XIII)

BEFORE the controversies which have arisen over the occurrence of reduction in plants can be settled or the problems as to the nature of fertilization can be attacked, a detailed study of dividing and quiescent plant cells is made necessary. The vegetative or typical division of plant cells from which the factors of sexuality and reduction are eliminated must be understood before deductions can be made as to the significance of the mode of origin and distribution of the chromosomes occurring in atypical divisions.

Accordingly, this research was undertaken with the hope of adding to our knowledge of the processes of vegetative cell division, and also of paving the way for further investigation of these processes as affected by variation of external conditions. The material used is Allium root tips, already known as exceptionally favorable for the study of karyokinesis. It was also considered an advantage, in order to secure a more thorough survey of the subject, to employ material which had furnished the text of other publications.

TECHNIQUE.

The following solutions were used for the fixation of the cells: chrom-acetic-osmic, both the weaker and stronger solutions as employed by Flemming, chrom-acetic acid (chromic acid 0.9 per cent. and acetic acid 0.1 per cent.); the solution recommended by Carnoy as composed of one part glacial acetic to six parts absolute alcohol and three of chloroform; and finally a solution made up of saturated picric acid one part, sublimate one part, to two parts of water. Cedar oil and xylol were used as clearing fluids. The best differentiation of the chromatic substance was obtained with Heidenhain's iron alum haematoxylin in combination with some cytoplasmic stain. The triple stain, safranin

gentian violet and orange G, followed by clove oil as a clearing agent, gave the best results in differentiating the nucleoli.

CELL DIFFERENTIATION.

The transition of meristem cells into permanent tissue is to be noted not only in the changes taking place in the nuclei, but also in the cytoplasm. As the cells develop into permanent tissue, large vacuoles appear in the cytoplasm, and the nuclei retreat into positions next to the walls, becoming then elliptical. Among the foremost of the problems suggested by watching the cells of the meristem pass out from their embryonic condition was that of the part played by the chromatin and nucleoli in this transformation of an embryonic cell into a tissue element.

A median longitudinal section reveals the large central cells and elongating cells which constitute the plerome. These large cells have correspondingly large nuclei and vacuoles in the cytoplasm and a relatively smaller amount of chromatin (*figs. 50, 51*). In the differentiation of these cells the chromatic substance first diminishes, and with this diminution it gradually loses the power of forming the karyokinetic figures. The great increase of the nucleoli follows from the quantitative reduction of the chromatin, while the energy that would have produced new cells becomes diverted into the expansion of the nucleus and cell body. The central cells reach a maximum of enlargement and then enter upon slow disorganization.

The cells of the plerome elongating to form procambium are early conspicuous, being marked off from the large central cells of the plerome on the one side and the periblem cells on the other by their narrow dimensions and elongating nuclei (*figs. 51–56*). An examination of these cells when in the act of dividing shows that the same general changes take place as in the meristem cells. The spireme stage is to be frequently seen, as well as the separation of the chromosomes. No cell, however, was seen which showed the chromosomes drawn into an equatorial plate. Their passage to the poles seems to follow directly upon the breaking of the spireme (*fig. 55*).

The changes leading to the formation of the elongated cells must be sought in the meristem cells from which these are

derived. Cells such as those shown in *fig. 53*, situated within the borders of the meristem region, whose shapes vary but slightly from the typical embryonic cell, have noticeable differentiations ushered in even before the membranes of the daughter nuclei are formed. In the cell shown in *fig. 53* of the anaphase the daughter chromosomes can be seen pushing into the cytoplasm as the spireme coils are being formed. This is the first visible elongation of the nucleus.

It cannot be said, then, that the peculiar shape of the nucleus is an adaptation to the shape of the cell, as in this case no appreciable elongation of the cell body has yet appeared. The causes which lead to this differentiation must be inherent in the chromatic substance where it is initiated.

In *figs. 52, 54* of the telophase the elongation of the daughter spiremes can be seen. These early elongations give to the daughter nuclei an amoeboid shape. Such appearances in the various stages furnish evidence that the chromatic substance is here of a fluid nature, with the power of independent motion, and not a substance passively drawn by contractile threads of kinoplasm.

When the cells by successive division have reached their maximum of elongation, further changes can be seen to have taken place within the nucleus. The chromatin, instead of being separable into groups of fours, as in the earlier stages of elongating cells and as described in this investigation for the meristem cells, becomes vacuolar, the chromatin irregularly massed, while the nucleoli, which up to this time have been undergoing a considerable increase in size, suffer fragmentation.

The observations then drawn from the anatomical differentiation in both types of cells found in the plerome point to the conclusion that the chromatic substance must play the chief rôle in the transformation of an embryonic cell into a tissue element.

The same general statements as to the part played by the chromatin in the transition of the meristem cells into periblem and dermatogen can be made. The shape assumed by the chromatic figure in karyokinesis determines the shape of the daughter cells. As the chromatic substance may elongate in the meristem

cell to form the elongated cell of the procambium, so it may assume a square figure and produce the daughter cell of the dermatogen.

In case of meristem cells destined to form the protecting cap, the chromatic substance gradually dwindles in amount without being accompanied by further increase of the cell body. The cytoplasm as well becomes reduced until finally both disappear.

The process of division of meristematic cells without regard to the problems suggested by differentiation will now be treated in sections.

THE ACHROMATIC FIGURE.

The enlargement of the nucleus due to the growth of the chromatin in the prophase of division is accompanied by significant changes in the appearance of the cytoplasm. In *figs. 2–5, 8, 9*, which show stages in the formation of the spireme, the cytoplasm appears to be uniform in structure. A comparison of the shapes of the nuclei indicates that the nuclei in the living cells must be amoeboid in these stages. As nearly as could be determined, the changes in the structural appearance of the cytoplasm in the immediate vicinity of the nucleus just precede or accompany the transverse breaking of the spireme coil into chromosomes.

The first indications of the achromatic figure are to be seen in the aggregations of cytoplasm which appear first and remain the densest at the poles of the nucleus. The shape which these aggregations assume, and hence the final shape of the achromatic figure, is dependent upon the shape and nature of the cell, as also possibly upon the fixative employed. The nucleus taken together with these cytoplasmic aggregations may be spherical, (*fig. 24*), or ovate (*fig. 18*), or elliptical (*fig. 19*). Occasionally these aggregations appear in such manner as to cause the chromatic figure to be obliquely oriented, and hence to alter the division plane from the usual one at right angles to the long axis of the cell.

Cells were seen in certain preparations, notably those fixed in chrom-acetic, in which the segments of a hyaline sphere seemed

to cap either pole of the nucleus (*fig. 11*) of a cell cut somewhat obliquely, the cytoplasmic aggregations appearing to extend over and around these segments (see also *fig. 24*). In such figures the clear space presents the same appearance and the same staining reaction as the nuclear interior.

A study of the nuclei in the prophase stages did not furnish satisfactory evidence that such hyaline segments capping the nucleus are regular stages in the formation of the achromatic figure. Although such appearances are to be frequently met with in material fixed in chrom-acetic, similar nuclei in the prophase show no hyaline sphere segments, but merely enlargements with cytoplasmic polar aggregations. Hence a question can be raised as to the existence of the hyaline polar caps in the living cells. Is this appearance a normal phenomenon produced by a withdrawal of cytoplasm from the pole of the nucleus, and to be referred to the turgescence of the living cell which causes the formation of a plasma membrane around the nuclear membrane? Or has this appearance been caused by fixation, the nucleus having become distorted and the membrane split or swollen? Or, thirdly, are these polar caps only optical effects resulting from looking down upon sections of an irregularly shaped nucleus, the lower boundary being projected beyond the upper boundary and hence producing the appearance of polar caps? A section of a nucleus shaped like a truncated cone can be conceived as presenting such an appearance.

In order to solve this problem, examination was made of many preparations fixed and stained by the methods previously outlined. If the hyaline caps are not produced by fixation, or are not optical effects produced from looking down upon sections of an amoeboid-shaped nucleus, but, on the contrary, are normal phases in the growth of the achromatic figure, their presence should be established in similar prophase stages and in all fixations which otherwise preserve the character of the cell contents. Preparations fixed in chrom-acetic showed such phenomena frequently, but by no means so constantly as to warrant their being considered a normal feature of division. *Figs. 19* and *20* represent a periblem cell drawn at upper and lower focus and

taken from a series fixed in picro-sublimate solution. No nuclei in the prophase showing hyaline caps at the poles were found in this series. In the drawing of the upper part of the nucleus the cytoplasmic aggregations may be seen at the poles. The nucleus has elongated in the direction of the long axis of the cell. Indications are also present of the ingrowing cytoplasmic fibrillae which later meet the linin strands that join the spireme coils to each other and to the nuclear membrane. *Fig. 18* from a series fixed by the same method represents a plerome cell in similar stage where the nuclear membrane has pushed out at the poles into the cytoplasmic aggregations. *Fig. 28* from the same series may be taken as a later stage, where the nuclear reticulum has completely joined with the cytoplasmic fibrillations. The stages in material fixed in Flemming presents configurations similar to those in the material fixed in picro-sublimate. An early stage from these preparations showing the pushing out of the nuclear membrane at the poles is seen in *fig. 26;* a somewhat later stage in *fig. 27*, where the cytoplasmic fibrillations can scarcely be distinguished from the nuclear reticulum. In *fig. 6*, from another series fixed in Flemming's solution in which the chromatin is well preserved, it would seem as though a vacuolization had taken place around the nucleus. There is no evidence of such vacuolization in *figs. 17* and *25*, taken from another series fixed in Flemming's solution, both cells being in the same section of the root tip. In both these cells the nuclear membrane can be clearly traced, marking out the nuclear space from the cytoplasm. *Fig. 25* is of a stage later than that shown in *fig. 17*. Here there are no signs of hyaline caps, but there is unmistakable evidence that the achromatic figure is formed by the elongation of the nucleus accompanied by the ingrowing of fibrillations from the cytoplasm. *Fig. 30*, from a preparation fixed in chrom-acetic, is a still later stage, where there is but the vaguest trace of a nuclear membrane. The achromatic figure is well formed and indistinctly multipolar. The term "monaxial multipolar," as applied by Hof to distinguish this form from the type of multipolar spindle found in the dividing macrospore, better describes the achromatic figure at this stage.

When the chromosomes are being drawn into an equatorial plate figure, as also when they have begun to recede to the polar figures, the fibers are more frequently found converging to a single point, though multipolar monaxial figures are the more characteristic. Certain cells from material fixed in Flemming show but traces of the achromatic figure, such traces being confined to the linin connecting adjacent chromosomes (*figs. 32, 33*). Fixatives such as chrom-acetic accentuate the fibrillar character of the plasm, while that of Flemming accentuates the granular character, showing fewer intercytoplasmic spaces. Compare *fig. 33* Flemming with *fig. 37* chrom-acetic.

Thus the evidence from the preparations examined points to the conclusion that the achromatic figure in Allium is derived from both cytoplasm and the elongated nucleus; that the cytoplasmic fibrillae normally fuse with the nuclear reticulum without the intervention of periplast formation, and form a multipolar monaxial spindle which may secondarily become bipolar.

The observations of other investigators regarding the achromatic figure in the division of meristematic cells is as follows:

Rosen (**8**) stated that in the cells of root tips of hyacinth a homogeneous plasm collects in a thin hyaline layer about the nucleus destined to divide. This layer he found to be concentrated at the opposite poles in the form of two conical caps in which rows of fibrillae originated close to the nuclear membrane.

Hof (**11**) stated that in Ephedra kinoplasmic bodies forming caps appeared simultaneously at the two diametrically opposite points of the nuclear surface. The polar caps soon took on the shape of sharp pointed spheres. In the interior of these spheres delicate threads form which finally fasten to the nuclear surface.

Němec (**9**) describes the fundament of the spindle as being bipolar in orientation from the beginning, appearing as a hyaline formation surrounding the nucleus and in the form of caps at the poles. He designated such caps as "periplasts." In another contribution upon the nuclear division of *Solanum tuberosum* he stated that, whereas in normal cells a hyaline periplast is formed as in Allium, in cells taken from wounded tubercles the threads grew out directly from the nuclear surface. He considered that

the reason for the failure of the hyaline periplasts to appear in the cells of the wounded tubercles is because of the greater size of the nuclei. Nuclei occurring in the tubercles experimented upon were 30 per cent. larger than those found in the growing points of root and stem.

His statement as to the cytoplasmic fibrillae in the cells of wounded tubercles growing out directly from the nuclear surface agrees with what I found in normal cells from the root tips of Allium fixed in Flemming and picro-sublimate solution. As to the appearance of the periplast, I cannot agree with Němec in considering it a normal feature in the process of vegetative cell division, and its absence caused by experimentation or otherwise disturbed conditions. In some cases its presence seems to be due to the action of fixatives or to the sectioning of an irregularly shaped nucleus.

Also as to the cytoplasmic aggregations which Strasburger and Hof consider as being made up of a specific substance, kinoplasm, the evidence derived from comparing the structural appearance of these aggregations with the appearance of the remainder of the cytoplasm in the various preparations does not seem to uphold such a conception. Their appearance rather justifies the view expressed by Wilson (**5**) and others that alveolar spheres, microsomes, granules, and fibrillae may be morphologically considered as but gradations of one structure.

CENTROSOMES.

In one case only, out of the many preparations of Allium examined, was there a substance visible which could be construed as a possible centrosome. This case is shown in *fig. 34* of a nucleus in the spireme stage with a dumb-bell-shaped body lying a little at the right of the lower pole. No astral rays are present, there being only a clear space about the body inclosed by a plasma membrane. The fact that the body was discrete and that its shape might indicate its undergoing a process of direct division led me to think that here might be a centrosome which by reason of its temporary character had before eluded observation. The section was from material killed in chrom-acetic and

stained with eosin and iron alum haematoxylin. After this cell was seen the material similarly treated was re-examined for bodies which might be interpreted as centrosomes, but with negative results.

The centrosome-like body was stained red by the eosin, as was the cytoplasm. As the centrosome of animal cells in all cases that I have observed stains black by the iron alum haematoxylin method, like the chromatin, the staining reaction argues against the interpretation of this body as a centrosome. The presence of the nuclear membrane still intact, together with the nucleolus within the spireme, shows conclusively that this body cannot be interpreted as a nucleolus. Whenever a nucleolus cast out into the cytoplasm is treated with iron alum and haematoxylin it takes on an intensely black stain (*fig. 36*).

On the examination of other cells on the same slide the cytoplasm was seen to contain bodies with similar staining reaction. These, however, showed no signs of division and their position in reference to the nucleus was inconstant. *Fig. 35*, of two cells in distinctly different phases of division, shows these appearances in the cytoplasm and indicates that their presence is not to be considered significant, but is caused by some imperfection in preservation, or else is due to some abnormal conditions in the cells such as the presence of parasites. Such appearances were not found in other material treated by the same or different methods.

Guignard (**2**) maintained the existence of centrosomes as dynamic organs in the cells of higher plants; Schaffner (**13**) described them as existing in Allium root tips; but Strasburger (**14**) and many other investigators find no evidence of their presence and have concluded that the centrosomes described as existing in the higher plants are in reality nucleoli, microsomes, or fixation products. Ch. Bernard (**16**) affirms the existence of centrospheres in *Lilium candidum*, but admits that they are variable in appearance. His figures showing bodies in the cytoplasm with clear spaces about them resemble mine of nucleoli degenerating in the cytoplasm.

The results of this investigation upon Allium can furnish no

positive evidence of bodies in the cytoplasm which can be interpreted as centrosomes.

THE NUCLEOLI.

The nucleoli, generally two in number, can be seen in fixed preparations of quiescent cells lying within a clear space surrounded by the chromatic network.

The size and shape of the nucleoli vary with the size and nature of the cell. Elongated cells have elongated nuclei and nucleoli (*fig. 55*), while the large central cells of the plerome have large, more or less spherical nuclei.

This power of accommodation of the nucleolus to the shape of the nucleus, together with its vacuolization and amoeboid contour, are direct indications of its essentially fluid nature. Referring to *fig. 50*, the large nucleoli in a central cell of the plerome can be seen. As these central cells recede in their multiplication from the zone of greatest growth, the nucleoli become relatively larger, the chromatic substance less conspicuous and abundant.

From these observations two conclusions might be drawn. The nucleoli, enlarging either by intussusception or apposition of particles coming from the cytoplasm, by their own growth may rob the chromatin elements of the nutriment necessary to enable them to develop the chromatic figure. Hence degeneration results, the line of broken-down cells giving rise to the central cylinder. Or the nucleoli may be thought of as accumulations of a substance which results from the reduction and degeneration of the chromatin. The latter seems more probable, as all the evidence obtained from cells which retain to the last their capacity for division points in the direction of a nucleolus arising from the disintegration of chromosomes into individual chromatin granules.

Rosen (**8**) states that in the hyacinth the nucleolus melts away during the formation of the spindle. In one series of sections only obtained from the hyacinth he found nucleoli cast into the cytoplasm. He offers the two following explanations for the difference in these series: special conditions of growth and nourishment might bring about the expulsion of the nucleoli

from the mitotic figure, or karyokinesis might vary in this particular point on account of the many varieties of the cultivated hyacinth.

This persistence of the nucleoli after the formation of the achromatic figure, which Rosen found in only a small portion of his hyacinth material, I found in all the material examined, from tips of Allium just started within the bulb and from those grown in water or solutions for some time. The duration of the nucleoli varies. I have never seen any signs of the presence of the nucleolus as a stainable body in the spindle space or in the cytoplasm after the daughter chromosomes have begun their movement toward the poles. *Figs. 2–30* show the condition of the nucleoli as the formation of the achromatic figure advances; *figs. 36, 37* are chosen from the many cases observed showing their dissolution in the cytoplasm. These go to prove that in Allium at least the nucleoli do not furnish to any appreciable degree the material for the achromatic figure, as Strasburger (**14**), Hof (**11**), and Němec (**9**) have claimed.

Neither did any cells yield evidence, such as Němec (**9**) gives in his work upon Allium, that the new nucleoli arise from the substances coming from the degeneration of the mantle fibers. The degenerating mantle fibers appear rather to be streams of granules which become diffused in the cytoplasm, to gather again at the line where the cell plate forms. In *figs. 45* and *46* are two periblem cells in stages closely succeeding one another and approximating the time for the appearance of the nucleoli. No aggregations of granules which stain like nucleoli could be observed in these cells or in any similar stages. If we consider the mantle fibers and the like in the living cells as streams of albuminoids and other substances issuing from the nuclear elements in their activity, then the apparent degeneration of the fibers merely indicates a diffusion of these dissolved substances and a lessening of their flow. These streams, after the chromosomes have arrived at the poles, are mainly directed in their course to the equatorial zone, separating the two daughter nuclei where the deposited substances lead to the building of the cell plate.

As stated in the section upon the chromatic figure, at the time

of the fusion of the chromosomes to form the spireme in the daughter nuclei, the spaces between the coils can be seen to be occupied by a diffusible and slightly stainable substance (*figs. 42–46*). This substance becomes denser at last, resolving into the bodies which are known as the nucleoli of the resting nucleus. I think that this substance results from the mere deposition of particles coming from the disintegration of chromosomes into tetrad chromatin granules and the reduction of the latter in size. These particles, of a more or less plastic nature, increasing in proportion to the reduction of the chromatin granules, are entangled in the chromatic network only to be released with the dissolution of the nuclear membrane at the next mitosis.

In connection with this view of the close relation of chromatin, linin, and nucleoli, it may be well to cite results of other investigators which accord in some measure with those secured in Allium.

In the case of Spirogyra, Meunier (**4**) and Mitzgewitsch (**12**) have claimed that during mitosis the nucleoli become converted into chromosomes and in the reconstructing daughter nuclei the chromosomes are transformed into nucleoli. Wisselingh (**15**) found that ten of the chromosomes arise from the nucleus, while the remaining two arise from the nucleolus. Hertwig (**10**) states in regard to the nuclear division of Actinosphaerium that the nucleoli may be classed as of two kinds, those containing chromatic material and those free from chromatin. The latter he terms plastin nucleoli. They originate as small vesicles within the chromatin bridges. His conclusion is the same as I reached in this investigation, namely that the material of the nucleoli was originally contained in the chromatin bridges. I would also add that in Allium the chromatin bridges are in turn derived from material originally contained in the chromosomes and result from their quantitative reduction.

Since Strasburger (**14**) holds that the nucleoli of the higher plants are converted into the kinoplasm of the achromatic figure, he considers that the plastin nucleoli described by Hertwig are not at all analogous to those found in higher plants.

Researches upon forms of the lower plants and animals indi-

cate that chromatin, linin, and nucleoli are of the same substance, the form and amount of which vary as the nucleus is quiescent or actively dividing. If then the nucleoli of the higher plants are not genetically derived from the chromatic substance, but, as Strasburger holds, come from the degeneration of the mantle fibers, then the function and mode of origin of these nucleoli must have undergone a radical change in the course of evolution. Strasburger attributes this difference in the function of the nucleoli in the higher plants from that found in lower forms to the absence of centrosomes.

The view expressed in this investigation that the nucleoli are accumulations resulting from the quantitative reduction of the chromatin is not only in harmony with the evidence derived from lower forms, but better explains the conditions observable in the plerome cells which have no use for material with which to manufacture achromatic figures.

THE CHROMATIC FIGURE.

The chromatic granules of meristematic cells that are in a quiescent state are distributed in the linin network, but lie at the periphery of the nucleus rather than uniformly distributed, while the linin strands can be seen anastomosing with the more centrally lying nucleoli. In these nuclei the granules appear so minute even with the one-twelfth inch homogeneous immersion that no satisfactory evidence was obtained as to whether they have a definite arrangement. That they do not always appear to be of equal size can be seen by inspecting the lower right-hand cell shown in *fig. 1*. This variation may be only apparent, due possibly to inequalities of fixation or staining, or in some cases to an optical appearance produced by looking upon several granules overlying one another in the successively superimposed strands of the network. In cells, however, where the beginning of the enlargement of the nucleus indicates an approaching division, the network appears to consist of strands each of which is double; the granules that lie opposite each other in each of the halves of the strand are connected by cross bridges of linin. *Fig. 2* shows a cell cut crosswise, in which appear the first indications of the double nature of the strands of this network.

This condition is especially to be observed in a few of the strands which are more favorably placed near the periphery. *Fig. 3* represents a similar cell cut lengthwise. As the nucleus enlarges still more, these double strands become more evident and regular in their arrangement, until we have the condition shown in the two periblem cells (*fig. 4*). Here the strands pass around the inner surface of the nucleus in what appears to be a more or less regular and continuous spiral, while the nucleolus still holds its central position within.

While bridges of the linin substance appear at first sight to connect the granules in pairs only, it is possible that the conditions are more complicated even at this stage, and that the chromatic thread which seems to be composed of only two parallel threads is in reality made up of four such parts. Such quadripartite thread with chromatic granules regularly arranged might give the appearance of being only bipartite, owing to the fact that, when viewed in certain directions obliquely to the axis of the thread, the pairs of granules in the distant half might appear to alternate with those of the nearer half.

In Allium tips treated with Flemming fixative (weaker solution), and not overstained by the iron alum haematoxylin method, the linin connecting the granules is less conspicuous. The granules, although they can still be traced as lying in strands, are more isolated, and thus separated are seen to lie, not in groups of two, but in groups of four. The stages shown in *figs. 5* and *6* (Flemming fixative) are directly comparable with the stage in *fig. 4* (chrom-acetic fixative). The cell shown in *fig. 5* is a somewhat later stage of a periblem cell treated with Flemming fixative, while *figs. 7* and *8* show later stages from tips similarly treated. The effect of the osmic acid in combination with the chrom-acetic then, as seen by these figures, is to bring out with greater distinctness the arrangement of the granules into tetrads. The linin can be distinguished in the cells thus treated, but it is more obscure than in the cells treated with chrom-acetic alone.

It would be natural, from our preconceived ideas of the individuality of the chromatin granules and of the necessity of an

equal distribution of substance to the two daughter nuclei, to assume that this arrangement of granules into an apparently double strand results from the splitting of a single thread or series of granules, but the very minuteness of the granules in the stages preceding the formation of the spireme precludes any direct observation of such a division even if it takes place.

There are two ways in which one might explain the formation of quadripartite threads out of the network of the quiescent nucleus. We might imagine that in a row of self-propagating units each divides into two, the result being two parallel rows, and that then each of the resultants again divides into two, thus giving rise to the groups of four which are joined into strands by the linin. Judging, however, from what it is possible to observe in the quiescent nucleus and in the later stages of division, there is some evidence in favor of another explanation. The grouping of the granules into pairs, which are at least double and probably quadruple, can be seen in early stages back to the point where the granules are so fine and so closely massed together that they cannot be said to have any definite arrangement. It is conceivable, therefore, that such a tetrad condition may be permanent, the granules having an inherent tendency to group themselves into fours.

An examination of the large cells of the plerome, which by their extreme size and presence of large vacuoles indicates the loss of the power of division, yields evidence that the tetrad condition may be permanent. In *fig. 50*, taken from a large plerome cell which is later to break down to form a central vessel, and *fig. 51*, of cells elongating to form wood fibers, fixed in Flemming and stained by the iron alum haematoxylin method, the chromatic network has the appearance of strings of vacuoles, the borders of the vacuoles consisting of the chromatin substance. A comparison of these figures with those of the early prophase, such as *figs. 7* and *8*, shows similarity of structure. The condition seen in the plerome cells may be interpreted as the result of the linin connecting the successive groups of tetrads having become more stretched, the tetrad granules less conspicuous; the space in the center of each group of granules acquiring

the appearance of a vacuole, one of a series in a network. As the nucleus enters into a quiescent condition then, the spaces in the centers of the groups of tetrads become more marked, and the boundary lines of the chromatin granules more and more indefinite.

The history of the chromatin shows that up to the time of the formation of the equatorial plate the whole process can be summarized as consisting of the growth, aggregation, and fusion of tetrads into chromosomes; whereas the period from the formation of the equatorial plate to that of the daughter nuclei can be summarized as a process consisting of the disintegration of chromosomes into tetrads and the reduction of the latter in size. The times of the appearance and disappearance of tetrads then correspond with those of appearance and disappearance of a definite arrangement of the chromatin, and this holds for the nuclei which are about to divide as well as for those which have just arisen from division.

From the time when the double strands of granules are first evident until the spireme is conspicuous, there is an increasing stainability, condensation, and enlargement of the component granules. *Figs. 9* and *16* represent successive stages in the growth of the spireme thread before it has broken up into chromosomes. The linin connecting the coils is seen to persist, but the connecting bridges are reduced in number.

These linin connections never completely disappear, although the quantity of linin varies with the stage of division. The linin strands which persist in the late spireme are more deeply stainable than the earlier connecting bridges. This suggests that this reticulum may arise, concomitantly with the growth of the chromatin, from the fusion of some of the earlier connections, while other connections are torn apart with the growth and consequent pulling apart of the coils. A cross-section of the spireme loop taken in early stages shows it to consist of four granules joined by the linin in the form of a square; a cross-section taken at stages immediately preceding that of its maximum size shows that the granules have approached one another in their growth. Its structure is thus seen to be, not that of a homogeneous single

or double thread, but that of a band composed of a series of chromatin masses joined together in rings, each ring being separable into four primary masses of chromatin. Later, at the time of the formation of the equatorial plate and when the chromatin has reached its maximum size, the four masses have by their growth fused with one another into a ring, the succession of rings resulting in the formation of a more or less continuous tube. In *figs. 13* and *16*, longitudinal sections of periblem cells giving surface views of the coils in the nucleus, some of the loops have been cut transversely and thus give end views of the spireme. Views of both the ends and sides of the threads are of course necessary for the formation of an opinion as to the real condition of the chromatic substance at this stage. From a comparison of such views it is evident that the thread is now a tubular structure, the walls being composed of the four more or less completely fused elements of the quadripartite stage. The more completely fused the chromatin masses, the straighter and more sharply defined is the edge of the spireme thread. Its contour varies with the age of the spireme and with the nature of the cell. In many cases (*fig. 10*) the spireme appears as a double homogeneous thread with clean-cut edge. In other cases (*fig. 9*) it has a moniliform appearance, the ring structure being more evident as the component chromatin masses are further apart. In the cross-section of the cell shown in *fig. 7* all the sections of the coil are transverse to the direction of the spireme thread. Groups of the enlarging tetrads can be seen joined to one another by the connecting linin substance. When the chromatin is not overstained and a surface view of the spireme is obtained, its appearance is that of a longitudinally split thread, the split, however, never being sharply defined. *Figs. 11* and *16* show this apparent longitudinal splitting, while in *figs. 9* and *14* the appearance, instead of resembling a split, is like a series of separate vacuoles. The apparent longitudinal splitting results from looking down upon the succession of rings formed by the incomplete fusion of the tetrads. The rings are less dense at the junction of the component masses, so that a surface view is that of two dense chromatin masses joined by the less dense linin;

or if the linin has broken down as in later stages, the split is the result of looking down upon the vacuoles which were formerly inclosed by the tetrads. That the split is not sharply defined is due to the persistence of the less deeply stained linin substance, which still connects in an uneven manner the masses of chromatin.

The growth and extension of the chromatic figure imply a correlated extension of the nucleus until the nuclear membrane breaks as a result of the interior pressure. Previous to the disruption of the nuclear membrane, the coils of the spireme have been quite regularly arranged within the nucleus, as shown in *figs. 14* and *15*, following the same arrangement that is to be seen in the early spireme, *fig. 4*. With the weakening of the membrane or closely following its dissolution, and with the consequent changes in pressure, the coils of the spireme break transversely at the places where they were bent. This breaking does not imply that the segments of the spireme have become completely separated, for, as *fig. 30* shows, the linin substance may still connect the segments of the spireme into a more or less continuous thread.

The number of segments thus arising seems to be inconstant, apparently varying from ten to thirty or more. There is a great deal of uncertainty, however, as to the number of segments, because many of them are cut in sectioning, and thus the apparent number is increased. A study of *fig. 30*, which shows thirty-eight such segments, would seem to indicate that none of the chromosomes there has been cut by the knife, because there exists linin between the successive segments of the bands. If a chromosome had been cut off square by the knife, its end would appear sharply truncated, with no linin substance connecting it with an adjacent chromosome. Such evidence as this and that presented by the cells shown in *figs. 37, a* and *b*, leads to the conclusion that in vegetative cells of Allium the spireme is not invariably broken into sixteen chromosomes, as has been maintained by other investigators, but that the number of segments is dependent upon the size and course of the spireme in the nucleus. This transverse breaking of the spireme into segments

can be of no significance in the distribution of the chromatin, as each chromosome is yet a tubular structure resulting from the fusion of the tetrads, unaffected by the breaking of the spireme.

After the nuclear membrane has become dissolved and the interchange of material between nucleus and cytoplasm is complete, the rings of chromatin split, causing the separation of the associated chromatin masses. *Figs. 32* and *37* show stages where the separation of the associated chromatin masses is well under way, while *fig. 33* shows a similar stage where some of the segments have been cut crosswise. The pairs of chromatin threads separate first from each other at the middle, while the ends may remain for some time attached.

In cells shown in *figs. 37a, 38*, we have the last stages in the separation of the chromosomes in the spireme segment. The ends of the chromosomes are still connected by the linin substance, though the separation is nearly complete. The structure of each chromosome at this stage, as seen both in surface view and in cross section, presents exactly the same appearance as that of the mother segment of the spireme, the only difference being that of size. After the splitting the chromatin closes up to form again the rings, thus making the tubular structure of the daughter chromosomes of the spireme. The end of each chromosome shows the ring formed of chromatin masses, the margin becoming indefinitely four-sided; the surface view gives the same vacuolar or longitudinally split appearance throughout their length. *Fig. 38* is of a stage showing the beginning of their movement toward the poles. The ring-like form, as seen from the end, and the split or vacuolar appearance, as seen in surface views, are here clearly marked, while in *fig. 41* the component tetrads can be traced. In *fig. 39* the cell was cut in such a plane as to give a longitudinal section of the chromosomes at one pole of the diaster and a cross section at the other pole. It can thus be seen from these figures that the disintegration of the rings into tetrads proceeds with the drawing apart of the chromosomes and with the beginning of their passage toward the poles.

The chromosomes having arrived at the poles become coiled, while their ends begin to approach one another. *Figs. 42–45*

represent sections of a cell, one drawn at high, the other at low, focus, so as to allow a complete reconstruction of the chromatic figure. At the right-hand upper pole of *fig. 44* it can be seen that one chromosome cut in cross section reveals the tetrad structure. The chromosomes can be seen now to have become more vacuolated. The adjacent chromosomes are being drawn together by the linin substance, which is more deeply stainable than the remains of the spindle fibers. A reconstruction of the sections of the cell indicate that in the fundament of the daughter nuclei a more or less continuous spireme coil is being formed.

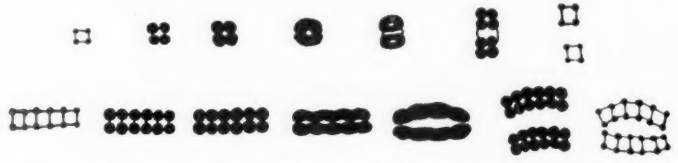
An opaque diffusible substance slightly stained by haematoxylin and other nuclear stains can be discovered between the chromosome coils. It appears to become denser as the vacuole-like spaces in the chromosomes increase in number (compare *figs. 42–46*). This substance has not before been recognizable. The chromosomes as they pass to the poles lie in a perfectly clear field, and it is not until they begin to fuse to form the spireme that this substance makes its appearance.

There is not a true vacuolization of the chromosomes, since the spaces are defined in too regular a fashion. This regular formation of the vacuoles in the rings is well illustrated in *fig. 46*. What we actually have is a resolution of the chromosomes into the component tetrads, with a gradual decrease in size of the chromatin bodies, apparently accompanied by an increase in volume of the linin. The loss of material accompanying the reduction in the size of the chromatin bodies is correlated with the increase of the linin and also with the presence of the diffusible substance which is deposited within the coils. In *fig. 47*, a longitudinal section of a periblem cell, are shown the first indications of a discrete body which can be termed a nucleolus. In *fig. 48*, where there is a continuous spireme, this is seen to lie within the coils and to occupy the same central position that the nucleoli of the quiescent nucleus hold after the nuclear membrane is completed. This nucleolus is only a condensation of the opaque substance to be seen in earlier stages between the chromosomes. In my opinion, it owes its origin to the chromatic bodies, being but a waste product of their activity.

In *fig. 49*, where the cell plate is nearly completed and the nuclear membranes are beginning to appear, the spireme coil is still to be traced. It is now seen to be composed of a double strand of granules which are connected with each other in pairs and with the adjacent strands by the linin. With the complete separation of the daughter nuclei by the cell plate these strands become finer and the grouping more indistinct, until finally all that can be discerned in the quiescent nucleus are the chromatin bodies in a network and the nucleoli.

A review of all the changes of the chromatic figure is now in order. A comparison of the stages which led up to the formation of the equatorial plate with stages extending from that point to the formation of the daughter nuclei shows that the first series represents a gradual growth of tetrads and their fusion to form chromosomes; these latter split, half passing to each pole and in its passage suffering disintegration into tetrads. The changes in the two series are identical, but take place in the reverse order. The conditions in *fig. 2*, a mother-cell preparing to divide, are directly comparable with those shown in the daughter nucleus represented in *fig. 49*. Similarly, *fig. 14* is comparable with *fig. 45*, and the chromosomes at one pole of the diaster in *fig. 41* with those in *figs. 7* and *8*.

The following diagrams show the order in which the changes in the chromatic figure occur.



Diagrams illustrating the morphology of the chromatic substance during karyokinesis: the diagrams in the upper series represent end views of a portion of the thread; those in the lower series, side views.

In reviewing the literature of the chromatic figure in plant cells, no account of such an origin, structure, and development as has just been described for Allium was found. The literature on the botanical side has been mainly concerned with contro-

versies over the number of chromosomes, the various shapes that they assume during division, and the manner of separation.

The work of Brauer (3) on the spematogenesis of *Ascaris megalocephala* has a direct bearing upon the results attained in the investigation of Allium. He states that in the passive nuclei of the spermatogonia the first preparation for the formation of the chromosomes is to be seen in the arrangement of the irregularly distributed granules into definite lines. The distinguishing feature of these nuclei in comparison with those which show no preparation for division is the presence of a sharp line between the chromatin granules, whereby these become arranged into two rows. In regard to the spermatocytes, he states also that when two threads do not lie directly over one another, or when through other change in their position an insight into their arrangement is made impossible, a division of the granules is everywhere to be seen. When a polar view of isolated groups of granules is obtained, each group can be seen to consist of four granules which lie arranged near one another in the same plane, each one being marked off from the neighboring ones by a well-defined fissure.

Brauer raised the question whether the splitting of the granules was from the beginning double, or whether the two splittings followed each other. He states that the granules in the earlier stages are too small and too numerous to allow a settlement of this question, yet he could discover in individual cases isolated granules composed of four elements.

The same question can be raised regarding the origin of the quadripartite granules of Allium in the earliest stages of the active nuclei in which any definite arrangement can be detected. Here too the evidence is of the same incomplete nature. Brauer does not describe for the early anaphase a resolution of the chromosomes first into double strands and then into quadripartite strands, each composed of a series of granules. Hence he has not raised the question, which I have previously discussed, whether, instead of a process of division of granules into fours to form the strands of the spireme, it may not be that from the beginning we have to do with a fusion of granules in fours.

Rosen (8) considered the formation of the spireme as due to the fusion of chromatic granules, but failed to get a polar view of the thread showing its quadripartite structure.

Němec (9) states that when the chromosomes have arrived at the poles, the chromatin coils send out pseudopodia-like continuations which bind opposite sides net-fashion. The chromatic substance gathers next on the periphery of the chromosomes, and dissolves into granules which wander into the pseudopodium-like continuations. In regard to the cell division of Solanum, Němec states that at the time when the spindle surrounding the nucleus is finished, the nuclear membrane vanishes and varicosities are to be seen in the chromatic threads. He thinks that the longitudinal splitting must occur at this time, as he found in thin sections of chromatin pieces in pairs extending into the periplast.

Hof (11) has a brief reference to what is doubtless the same condition which I have described in Allium. In stages of the dispireme, where the daughter nuclei are found, signs of a longitudinal splitting are rarely to be seen in the threads. The daughter nuclei present a structure similar to that shown by the nuclei of the prophase, except that they do not yet show the beginning of the enlargement of the nucleus. He thinks that very likely, owing to the quick succession of divisions in the cells of the meristematic tissue, those cells in which the longitudinal splitting is to be seen in the dispireme stage are to be considered as preparing for the ensuing division without the intervention of a resting stage. He does not hold this splitting to be a characteristic feature of the anaphase, as I do. Hof figures but two cells with signs of longitudinal splitting in the anaphase.

The fact that after this apparent longitudinal splitting has occurred in the chromosomes of the dispireme all stages can be found showing gradual reduction in size of the chromatin bodies and increase of the linin, is evidence that this is not a temporary phenomenon. A criterion for removal of all doubt that these stages in the late anaphase may have been mistaken for those of the early prophase is the presence of the incomplete cell plate.

Meves (17) describes vesicular chromosomes occurring in Paludina. The peculiar behavior of these chromosomes in their relation with the centrosomes makes it difficult to draw any analogies with the conditions found in Allium.

The interpretations which I have made do not refute what is a fairly well established fact, that in the rapidly dividing cells of meristematic tissue the daughter nuclei in the late anaphase often proceed to divide without the intervention of a resting stage or the formation of a nuclear membrane. It only reasserts, what Flemming (1) and other investigators have held, that the chromatin undergoes after the metaphase the same changes as before the metaphase, but in the reverse order. The history of the chromatin in cell divison can be characterized as made up of periods of growth, aggregation, and fusion, followed by periods of separation, disintegration, and reduction.

The literature now remains for consideration which bears upon the shape of the chromosomes and the manner of their separation.

Ishikawa (7) studied division in the epidermal cells of Allium buds. He found that coil to break up into sixteen pairs of chromosomes, generally of an equal length.

Belajeff (6) stated that in vegetative cell divisions, while the daughter chromosomes are yet bound to each other at their ends, a rhomboidal figure is formed. The U-forming daughter segments move apart and form daughter stars, one at each pole of the nuclear spindle. Belajeff maintains that this U-shape of the chromosomes is characteristic and peculiar to vegetative cell divisions, and that in the heterotypical form of division there are V-, Y-, and X-shaped figures which show longer and shorter arms.

Hof (11) finds that the chromosomes in the stage of the mother star in vegetative cell division have mostly the figure of J-forming threads, with arms of unequal length, although rhomboidal figures also occur.

Strasburger (14) criticises Belajeff's characterization of the three types of nuclear division based upon the form of the chromosomes. Neither the manner of insertion of the chromo-

somes in the spindle nor the definite lengths of the chromosome branches are considered by Strasburger as furnishing satisfactory marks for contrasting typical and atypical division in metaphytes. Strasburger found in the pollen mother-cells of Lilium and also of other forms that the daughter chromosomes at the beginning of the metaphase undergo a second longitudinal splitting. This takes place at right angles to the first.

Guignard (**2**) came to the same view as did Strasburger in regard to a second longitudinal splitting in the pollen mother-cells of *Najas major*.

This second longitudinal splitting described as occurring in the atypical divisions of cells Strasburger would make a distinguishing feature of their division, marking them out from typical divisions by this rather than by the form of the chromosomes or by the manner of insertion. Belajeff does not assent to the view that there is a second longitudinal splitting, but holds such **V**'s as consisting of two chromosomes bound together.

It is not within the province of the present investigation to go into the details of atypical divisions in plants. A comparison of Strasburger's figures with the structures seen in the typical division stages of Allium confirms me in the belief that even in the presence of this second longitudinal splitting, we have no feature which will distinguish atypical from typical division.

I think that this second longitudinal splitting, described by Strasburger and by other investigators as peculiar to atypical division, is the same phenomenon as that described by me as occurring in the typical division of Allium cells, namely, the apparent longitudinal splitting seen in the surface view at the beginning of the metaphase, and that it is due to the changing of the daughter chromosomes from tubular structures into the quadripartite threads. This change is but a reversal of the change which occurred before the metaphase.

Future research, I believe, will establish that the mechanism of cell division in both the typical and atypical forms is essentially the same.

CAMBRIDGE, MASS.

LITERATURE CITED.

1. FLEMMING, W., Zellsubstanz, Kern- und Zelltheilung. Leipzig. 1882.
2. GUIGNARD, L., Sur l'existence des "sphères attractives" dans les cellules végétales. Compt. Rend. **112**: 539–542. 1891.
———, Le développement du pollen et la réduction chromatique dans le *Naias major*. Arch. Anat. Mikr. **2**: 455–509. 1899.
3. BRAUER, A., Zur Kenntniss der Spermatogenese von *Ascaris megalocephala*. Arch. Anat. Mikr. **42**: 153–213. *pls. 11–13*. 1893.
4. MEUNIER, A., Le nucléole des Spirogyra. La Cellule **3**: 333–407. 1888.
5. WILSON, E. B., The structure of protoplasm. Science **10**: 33–45. 1899.
6. BELAJEFF, W., Zur Kenntniss der Karyokinesis bei den Pflanzen. Flora **79**: 430–442. 1894.
7. ISHIKAWA, M., Die Entwickelung der Pollenkörner von *Allium fistulosum* L. Jour. Coll. Sci. Tokyo **10**: 2. pp. 31. *pls. 2*. 1897.
8. ROSEN, F., Kerne und Kernkörperchen in meristematischen und sporogene Geweben. Cohn's Beitr. Biol. Pflanzen **7**: 225–312. *pls. 2–4*. 1896.
9. NĚMEC, B., Ueber Kern- und Zelltheilung bei *Solanum tuberosum*. Flora **86**: 214–227. *pls. 13–14*. 1899.
———, Zur Physiologie der Kern- und Zelltheilung. Bot. Centralbl. **77**: 241–251. 1899.
———, Ueber die karyokinetische Kerntheilung in der Würzelspitze von *Allium cepa*. Jahrb. Wis. Bot. **33**: 313–336. *pl. 3*. 1899.
10. HERTWIG, R., Ueber Kerntheilung, Richtungskörperbildung und Befruchtung von *Actinosphaerium Eichhorni*. pp. 104. *pls. 8*. Munich. 1898.
11. HOF, A. C., Histologische Studien an Vegetationspunkten. Bot. Centralbl. **76**: 65–69, 113–118, 166–171, 221–226. *pls. 3–4*. 1898.
12. MITZKEWITSCH, L., Ueber die Kerntheilung bei Spirogyra. Flora **85**: 81–124. *pl. 5*. 1898.
13. SCHAFFNER, J. H., Karyokinesis in the root tips of *Allium cepa*. BOT. GAZ. **26**: 225–238. *pls. 21–22*. 1898.
14. STRASBURGER, E., Histologische Beiträge **6**: 1900.
15. WISSELINGH, C. VAN, Ueber Kerntheilung bei Spirogyra. Flora **87**: 355–377. *pl. 15*. 1900.
16. BERNARD, C., Recherches sur les sphères attractives chez *Lilium candidum*, etc. Jour. Botanique **14**: 118–128, 177–188, 206–212. *pls. 4–5*. 1900.
17. MEVES, F., Ueber die sogenannten wurmförmigen Samenfäden von Paludina und über ihre Entwickelung. Anat. Anzeiger **19**: Ergänzungshefte 23–36. *pls. 8*. 1901.

EXPLANATION OF PLATES XI–XIII.

FIG. 1. Cross section showing stages after the spireme has broken into chromosomes, and a quiescent nucleus; cells killed in Flemming fixative

(weaker solution); stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG 2. Cross section of meristem nucleus where the spireme is first becoming evident; cell killed six hours in Flemming (weaker solution); stained with iron alum, eosin, and Heidenhain's haematoxylin. ×2440.

FIG. 3. Longitudinal section of periblem cell showing quadripartite structure of the early spireme; Flemming twenty-four hours; iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 4. Longitudinal sections of two dermatogen cells showing the early spireme; fixed in chrom-acetic; stained with eosin, iron alum, and Heidenhain's haematoxylin. × 2440.

FIG. 5. Longitudinal section of a periblem cell showing the quadripartite structure of the early spireme; killed in Flemming's weaker solution twenty-four hours; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 6. Longitudinal section of two periblem cells showing quadripartite structure of early spireme; killed in Flemming's weaker solution; the upper cell showing the withdrawal of the cytoplasm from the poles of the nucleus, giving the appearance of hyaline caps; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 7. Cross section of periblem cell showing the quadripartite structure of the spireme; killed in Flemming's weaker solution six hours; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 8. Longitudinal section of a periblem cell showing the quadripartite structure of the spireme in a somewhat later stage; killed with chrom-acetic; stained with orange G and Heidenhain's haematoxylin with iron alum. × 2440.

Fig. 9. Cross section of periblem cell showing a later stage of the spireme and the nucleus beginning to elongate; killed with chrom-acetic and stained with orange G in combination with Heidenhain's haematoxylin and iron alum. × 2440.

FIG. 10. Longitudinal section of a periblem cell with the spireme of smooth contour; killed in chrom-acetic; stained with safranin, gentian violet, and orange G. × 2440.

FIGS. 11–12. A longitudinal section of a periblem cell drawn at upper and lower focus, showing the appearance of hyaline polar caps and ingrowing cytoplasmic fibrillations; killed with chrom-acetic; stained with safranin and gentian violet. × 1750.

FIG. 13. Longitudinal section of a periblem cell; the cell is sectioned in such manner as to give at the same time an end and surface view of the spireme thread; the end view shows the quadripartite structure, while the surface view shows the fusion of the component granules into a continuous thread; the elongation of the nucleus can also be noted here; killed with Flemming's weaker solution; stained with iron alum and Heidenhain's haematoxylin. × 2440.

FIG. 14. A longitudinal section of a periblem cell showing a late stage in the spireme, where it has a vacuolar appearance with prominent connecting linin bridges; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 15. A longitudinal section of a periblem cell showing the elongation of the nucleus: killed in chrom-acetic; stained with eosin and Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 16. Longitudinal sections of two periblem cells in the late spireme stage; the lower nucleus shows the appearance of hyaline caps; killed with chrom-acetic; stained with eosin and Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 17. Longitudinal section of periblem cell showing ovoid enlargement of the nucleus; killed in Flemming's weaker solution; stained with eosin and Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 18. Longitudinal section of a periblem cell showing the elongated nucleus after the breaking of the spireme thread, also the aggregation of cytoplasm at the poles; killed in picro-sublimate; stained with Heidenhain's haematoxylin and iron alum in combination with eosin. × 2440.

FIG. 19. Longitudinal section of a periblem cell with the cell surface in focus, showing the elongated shape of the nucleus and its relation to the aggregations of cytoplasm; killed in picro-sublimate; stained with Heidenhain's haematoxylin with iron alum in combination with eosin. × 2440.

FIG. 20. The same cell with the central portion in focus.

FIG. 21. Longitudinal section of a periblem showing the beginning of the dissolution of the nuclear membrane; killed in chrom-acetic; stained with Heidenhain's haematoxylin in combination with orange G. × 2440.

FIGS. 22–23. Longitudinal section of a periblem cell showing the lower and upper part of the cell; killed in chrom-acetic; stained with safranin, gentian violet, and orange G. × 1750.

FIG. 24. Longitudinal section of a dermatogen cell showing the hyaline cap appearance; killed in chrom-acetic; stained with Heidenhain's haematoxylin in combination with eosin. × 2440.

FIG. 25. Longitudinal section of a periblem cell showing the fusion of the fibrillations from the cytoplasm with the nuclear reticulum; killed in Flemming's weaker solution 24 hours; stained with Heidenhain's haematoxylin in combination with eosin, × 2440.

FIG. 26. Longitudinal section of two periblem cells after the spireme has broken up into chromosomes, showing the disappearance of the nuclear membrane and the ingrowing of the fibrillations of the cytoplasm; killed in Flemming's weaker solution twenty-four hours; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 27. Longitudinal section of a periblem cell showing an early stage in the formation of the achromatic figure; killed in Flemming's weaker solution twenty-four hours; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 28. Longitudinal section of a periblem cell showing early stage in the formation of the achromatic figure; killed in picro-sublimate; stained with Heidenhain's haematoxylin in combination with eosin. × 2440.

FIG. 29. Longitudinal section of a periblem cell showing the formation of a bipolar spindle; killed in chrom-acetic; stained with safranin and gentian violet. × 1750.

FIG. 30. Longitudinal section of a dermatogen cell showing the last vestiges of a nuclear membrane and the union of the fibrillations from the cytoplasm with the nuclear reticulum to form the achromatic figure; a nucleolus somewhat reduced in size can be seen in the spireme; killed in chrom-acetic; stained in safranin, gentian violet, and orange G. × 1750.

FIG. 31. Longitudinal section of a dermatogen cell in a later stage showing the chromosomes beginning to form into equatorial plate; killed in chrom-acetic; stained with Heidenhain's haematoxylin and iron alum in combination with orange G. × 1750.

FIG. 33. Longitudinal section of a dermatogen cell showing the formation of equatorial plate and the beginning of the separation of the chromosomes; absence of kinoplasm is to be noted in this preparation; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 33. Longitudinal section of a periblem cell, in stage just following the preceding; some of the chromosomes have been cut transversely in the act of separation; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin and iron alum in combination with eosin. × 2440.

FIG. 34. Longitudinal sections of two periblem cells in the stages of spireme and diaster; the upper cell shows a centrosome-like body below and at the right of the nucleus; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum in combination with eosin. × 2440.

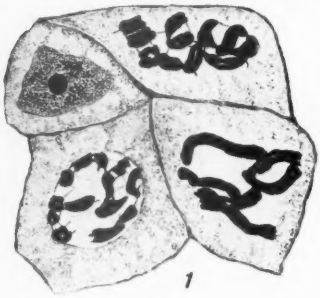
FIG. 35. Two cells from the same slide as the preceding showing similar bodies in the cytoplasm.

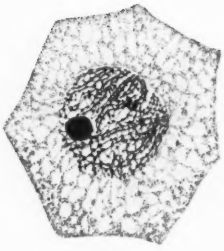
FIG. 36. Longitudinal section of dermatogen cell showing late persistence of the nucleolus in the achromatic figure; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum in combination with orange G. × 2440.

FIG. 37. Longitudinal section of periblem cell showing separation of chromosomes; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 38. Longitudinal section of periblem cell showing the passing of the daughter chromosomes to the poles, the vacuolar appearance and the beginning of their disintegration into tetrads; killed in Flemming's weaker solution twenty-four hours; stained with Heidenhain's haematoxylin with iron alum. × 4240.

FIG. 39. Periblem cell cut obliquely, giving both cross and longitudinal sections of the diaster; the apparent second longitudinal splitting is to be


1

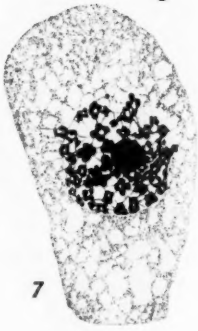

2

3

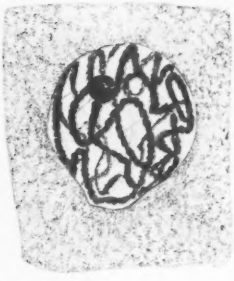
4

5

6


7

8


9

10

11

12

13

14

2

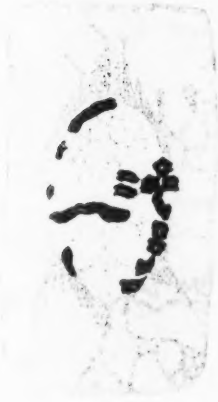
MERRIMAN, DEL.

15

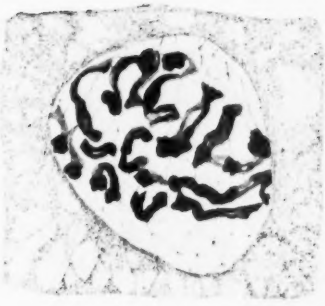
16

18

22



19

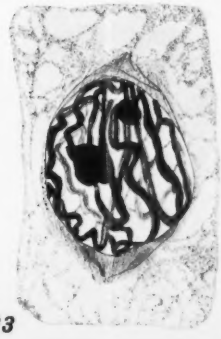


17

24

20

21

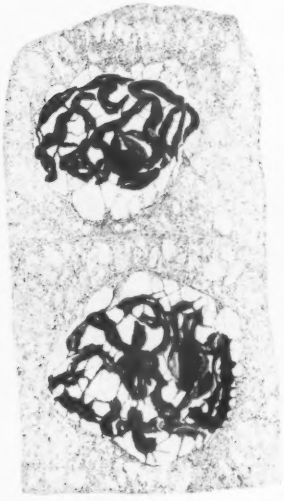


23

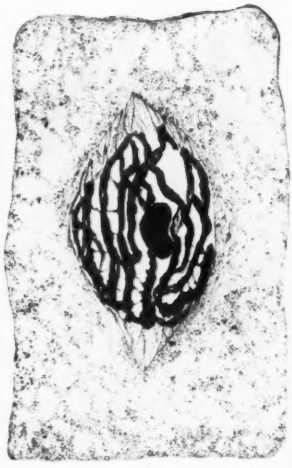
25

RIMAN on ALLIUM.

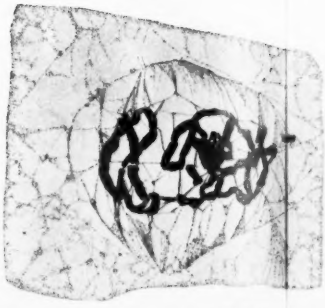
HELIOTYPE CO., BOSTON



26



28



30

29

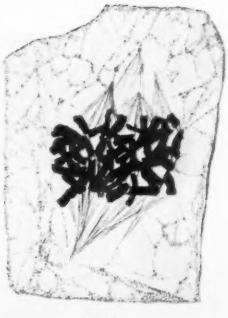
32

27

33

36

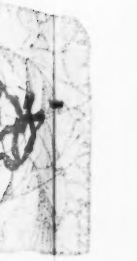
37a



37b

37c

MERRIMAN, DEL.

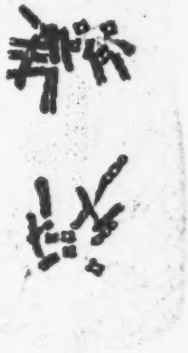


31

34

35

39



41

36

38

40

42

43

44

45

HELIOTYPE CO., BOSTON.

MERRIMAN, DEL.

HELIOTYPE CO., BOSTON.

MERRIMAN on ALLIUM.

noted here in surface view, the tetrad structure in the end view; killed in Flemming's weaker solution six hours; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 40. Longitudinal section of a periblem cell in the metaphase; killed in chrom-acetic; stained with Heidenhain's haematoxylin and orange G. × 2440.

FIG. 41. Longitudinal section of a periblem cell in the metaphase showing the disintegration of the chromosomes into tetrads; killed in chrom-acetic; stained with Delafield's haematoxylin in combination with eosin. × 2440.

FIGS. 42–45. From a longitudinal section of a periblem cell, drawn in order of sectioning so as to admit of reconstruction; this stage was considered important as showing the disintegration into tetrads of the chromosomes, their fusion into spireme, the appearance of the linin interspireme bridges, and the substance which later resolves into the nucleoli; killed with chrom-acetic; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIG. 46. Longitudinal section of periblem cell showing the chromatin masses arranged in rings; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIGS. 47–48. Longitudinal sections of periblem cells in the anaphase; the nucleoli have appeared as discrete bodies; the nuclear membranes are as yet unformed; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum in combination with orange G. × 2440.

FIG. 49. Longitudinal section of periblem cells in the late anaphase; the double thread in the spireme is conspicuous in the reconstructing daughter nuclei; the cell wall is nearly completed; drawn with Leitz one-twelfth oil immersion and Zeiss ocular 12.

FIGS. 50–51. Longitudinal sections of cells of plerome, the large central cells and the elongating cells showing the structure of the chromatic network; killed in Flemming's weaker solution; stained with Heidenhain's haematoxylin with iron alum. × 2440.

FIGS. 52–56. Longitudinal sections of the elongating cells of the plerome, showing the peculiarities in structure and behavior of the chromosomes; killed in chrom-acetic; stained with Heidenhain's haematoxylin with iron alum.

UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS. XXV.[1]

JOHN DONNELL SMITH.

Sloanea meianthera Donn. Sm. (§ AXILLIFLORAE BRACHYSTACHYAE Benth.).— Folia opposita lanceolato-elliptica caudato-acuminata basi acuta supra glabra subtus nervis puberula, petiolis apice subtus incrassatis. Racemi cinereo-pubescentes, floribus inter minimos. Stamina glabra sepalis longiora antheras minimas muticas 3–4-plo superantia. Discus orbicularis. Ovarium canopilosum, stylo apice 4-fido.

Arbor, ramulis superne sulcatis et petiolis cinereo-pubescentibus. Folia subcoriacea integra 8–18 cm longa medio 2.5–5.5 cm lata, nervis lateralibus utrinque 7–8, petiolis 1–2 cm longis, stipulis minutis caducis. Racemi subsessiles 1.5–3 cm longi laxe 5–9-flori, bracteolis oblongo-ovatis 1 mm longis, pedicellis infimis 5–7 mm longis, superioribus quam flores brevioribus. Sepala 4 pubescentia ovata vel lanceolato-ovata 2–2.5 mm longa. Stamina 2.5–3.8 mm longa, antheris oblongo-ellipsoideis 0.8 mm longis rima elongata dehiscentibus. Discus crassus 2–3 mm-diametralis pubescens. Ovarium pilis densis obtectum ovoideum cum stylo aequilongo glabro adjecto 3–4 mm longum. Capsula desideratur.— Ad *S. obtusifoliam* Schumann et *S. obtusam* Schumann floribus accedens ab utraque foliis recedit.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350 m, Febr. 1902, *von Tuerckheim*, n. 8191 ex Pl. Guat. &c., quas ed. Donn. Sm.

Platymiscium dimorphandrum Donn. Sm.— Foliola 5 membranacea minutissime reticulata oblongo-elliptica obtuse acuminata basi acuta. Racemi fasciculati longissimi fere e basi floribundi. Calyx majusculus obpyramidalis, dentibus 3 acuminato-triangularibus, 2 superioribus in unum obtusum bidenticulatum coalitis. Stamina alterna sterilia, vexillare liberum.

Arbor. Stipulae ovatae vel oblongae 10–14 mm longae. Folia cum petiolo 3.5–6 cm longo adjecto 15–22 cm longa, foliolis 6–12 cm longis 2–4 cm latis, petiolulo terminali 2–2.5 cm longo lateralibus bis terve longiore. Racemi glabri 16–25 cm longi, pedicellis singulis 1–1.5 mm longis, bracteis bracteolisque vix ullis. Calycis tubus 3–3.5 mm altus basi acutus, dentes inferiores 1–1.5 mm longi. Vexillum orbiculare basi cuneatum 1 cm longum alas vix superans

[1] Continued from BOT. GAZ. **35**: 9. 1903.

carina longius. Stamina fertilia 7 mm longa, sterilia paulo breviora antheris parvulis cassis instructa. Ovarium stipite brevius stylo aequilongum. Legumen ignotum.—Species et calyce et staminibus insignis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350 m, Mart. 1092, *von Tuerckheim*, n. 8199 ex Pl. Guat. &c., quas ed. Donn. Sm.

Cassia anisopetala Donn. Sm. (§ CHAMAESENNA DC.).—Aculeis stipularibus recurvis armata. Folia eglandulosa, foliolis 4-jugis rarius hinc inde 2–3-jugis lanceolato-ellipticis vel -oblongis utrinque acutis supra nitidis subtus pubescentibus. Racemi foliis sublongiores, pedicellis filiformibus. Petala stipitata valde inaequalia, inferiorum biformium altero maximo incurvato concavo basi rotundo, altero cum superioribus eo minoribus et longius unguiculatis obovato-oblongo basi attenuato. Stamen infimum ceteris majus.

Frutex undique praeter faciem superiorem foliolorum et flores primum aureo-deinde cinereo-pubescens. Folia cum petiolo 3–5 cm longo adjecto 10–18 cm longa, foliolis 4–8 cm longis 2–3 cm latis, inferioribus minoribus et magis ellipticis, petiolulis 5–6 mm longis. Racemi cum pedunculo 4–8 cm longo adjecto 13–21 cm longi, pedicellis 2 cm longis. Sepala interiora ovalia circiter 5–6 mm longa 2 exterioribus oblongis dimidio longiora. Petalorum inferiorum majus 2 cm longum 8 mm latum basi ascendens oblongum inferne dimidiatum stamen maximum complectens, minus 14 mm longum, superioribus 8–10 mm longis. Stamina perfecta 7 sepalis interioribus subaequilonga, infimum 7 mm longum, antheris 3.5–4 mm longis poro duplice apiculatis pilosiusculis. Staminodia 3 staminibus aequilonga, antheris cassis oblongis quam filamenta brevioribus. Ovarium glabrum stipitatum, ovulis verticaliter compressis. Legumen desideratur.—Inter species aculeatas paueas adhuc cognitas haec et foliis et petalis optime distincta.

In planetiebus ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350 m, Mart. 1902, *von Tuerckheim*, n. 8194 ex Pl. Guat. &c., quas ed. Donn. Sm.

Miconia involucrata Donn. Sm. (§ JUCUNDA Naud.).—Folia subsessilia oblongo-vel obovato-elliptica caudato-acuminata basi rotundata vel basi ipsa anguste obtusa subintegra supra glabra subtus minutissime puberula 7-plinervia. Panicula stellato-canescens laxe ramosa, ramis secundariis brevissimis apice capituliferis, capitulis trifloris bractea singula involucratis, floribus lateralibus unibracteolatis, centrali ebracteolato.

Arbor, ramis fistulosis. Folia subcoriacea discoloria 24–35 cm longa 10–16 cm lata nonnunquam disparia subtus pallide cinnamomea, nervis lateralibus prope basin limbi utrinque 3–6 tenuibus brevibus, superioribus apicem limbi

attingentibus utrinque 3, summis 5–10^{cm} supra basin a costa secedentibus, petiolis 5–6^{mm} longis. Panicula terminalis pyramidata cum pedunculo 6–10^{cm} longo adjecto 20–25^{cm} longa, inflorescentiae nondum evolutae capitulis glomeratis vel breviter spicatis, bractea orbiculari bracteolisque 1^{cm} longis stellato-canescentibus jam ante anthesin caducis, floribus 6-meris. Calycis canescentis tubus 7^{mm} longus, lobi lanceolati 5^{mm} longi. Petala oblonga 7^{mm} longa obtusa alba. Stamina violacea, antheris 1^{cm} longis filamenta superantibus, loculis undulatis, connectivo ecalcarato basi incrassato. Ovarium tubo calycis 3-plo brevius 4-loculare, stylo 17^{mm} longo. Bacca ignota.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Sept. 1901, *von Tuerckheim*, n. 8204 ex Pl. Guat. &c., quas ed. Donn. Sm.

Arthrostemma apodocarpum Donn. Sm.—Folia parva lanceolata vel lanceolato-elliptica vel ovata sursum subsensim acuminata in petiolum longiusculum contracto-acuminata et decurrentia supra sparsim setulosa subtus glabra et pallida opaca 5-nervia, margine appresse arguteque ciliato-serrulato. Flores subsessiles. Stamina parum inaequalia, filamentis complanatis glandulari-pilosis. Capsula cylindrica basi attenuata.

Caules e rhizomate repente ascendentes 3–5.5^{dm} longi herbacei sicut inflorescentia pilis glanduliferis passim conspersi. Folia 28–45^{mm} longa 15–22^{mm} lata nervis basilaribus latis fuscis subtus tantum notata ceterum enervia, petiolis 10–15^{mm} longis. Cyma dichotoma laxe pauciflora. Calycis tubus clavato-oblongus 8^{mm} longus, limbus patulus triangulari-dentatus 3^{mm} latus. Petala 15^{mm} longa. Staminum majorum filamenta 5^{mm}, minorum 4^{mm} longa, antheris parvulis. Capsula sessilis 16-18^{mm} longa calycis fructiferis tubum aequans eique adhaerens.—*A. parvifolio* Cogn. proximum.

Inter rupes ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jan. 1902, *von Tuerckheim*, n. 8208 ex Pl. Guat. &c., quas ed. Donn. Sm.

Oreopanax meiocephalum Donn. Sm.—Praeter inflorescentiam glaberrimum. Folia simplicia integra lineari-lanceolata longe acutissimeque acuminata basi acuta breviter trinervia cum petiolo bis terve breviore utrinque incrassato subgeniculato-articulata. Panicula parva laxiflora, pedicellis gracilibus, capitulis subglabris parvis laxe 5-8-floris.

Ramuli cortice exfoliante pallidi. Folia crasse coriacea utrinque nitida 14–23^{cm} longa 3–4.5^{cm} lata, costa valida, nervis basilaribus prope marginem ascendentibus et 5–6^{cm} longis, petiolis validis 5–12^{cm} longis. Panicula leviter stellulato-pubescens circiter 8^{cm} alta, ramis inferioribus 5-6^{cm} longis, pedicellis 5–8^{mm} longis, capitulis 3^{mm}-diametralibus. Petala saepius 5 filamentis aequilonga 1.25^{mm} longa. Styli coaliti. Flores feminini fructusque desunt.

Pansamalá, Depart. Alta Verapaz, Guat., alt. 1250^{m}, Apr. 1889, *J. Donnell Smith*, n. 1743 ex Pl. Guat. &c., quas ed. Donn. Sm.—(Sub *O. oligocarpo* Donn. Sm. olim distributum.)

Solanum evolvulifolium Greenman.—Caulis scandens gracilis parce ramosus bifariam pubescens. Folia alterna petiolata solitaria oblongo-ovata vel oblongo-lanceolata. Flores in cincinno simplici vel bifurcato dispositi. Calyx cyathiformis breviter 5-lobatus. Corolla rotata.

Folia 1.5–3.5^{cm} longa 0.6—1.8^{cm} lata breviter acuminata acuta integra vel repando-undulata ad basin rotundata vel subcordata supra glabra vel solum in nervo medio hinc inde pilosula subtus glabra. Petioli 1.5–4^{mm} longi pubescentes. Calyx 3–4^{mm} altus breviter 5-lobatus, lobis submucronato-acutis. Corolla rotata circiter 12^{mm} longa alba, lobis lanceolato-oblongis 8^{mm} longis acutis plus minusve prope marginem puberulis ciliatis. Stamina 5 (cum vel absque sexto perabortivo) aequalia. Antherae filamentis longiores apice biporosae tardius longitudinaliter dehiscentes. Gynoecium glabrum. Bacca ovata vel subrotundata 7–14^{mm} longa. Semina circiter 2.5^{mm} longa.—*S. boerhaavifolio* Sendt. Brasiliensi habitu simile differt petiolis brevioribus et foliis cordatis.

La Palma, Prov. San José, Cost., alt. 1460^{m}, Sept. 1898, *H. Pittier*, n. 7413 ex Pl. Guat. &c., quas ed. Donn. Sm. (n. 12615 herb. nat. Cost.); Nov. 1897, *C. Wercklé*, n. 11599 herb. nat. Cost.

Solanum mitratum Greenman.—Caulis herbaceus glaber flexuosus. Folia solitaria vel gemina ovata vel lanceolata in petiolum brevem attenuata. Flores axillares solitarii vel gemini. Pedicelli plerumque petiolo longiores. Calyx turbinatus truncatus vel crenatus glaber. Corolla 5-partita purpurea.

Folia 5–15^{cm} longa 1.5–6^{cm} lata acuminata acuta integra supra viridia subtus pallidiora utrinque glabra. Pedicelli 1.5–2^{cm} longi plerumque ad apicem incrassati. Calyx 2–3^{cm} altus 10-nervatus paullo costatus. Corolla 5-partita purpurea, tubo brevi 3–4^{mm} longo, lobis lanceolatis acutis 3-nervatis. Antherae in tubo subconniventes. Bacca immatura subglobosa 8^{mm} diam., matura non visa.—*S. synanthero* Sendt. proximum differt caule herbaceo, petiolis brevibus, floribus paucioribus et pedicellis ad apicem incrassatis.

Atirro, Prov. Cartago, Cost., alt. 600^{m}, Apr. 1896, *J. Donnell Smith*, n. 6673 ex Pl. Guat. &c., quas ed. Donn. Sm.—San Pedro Sula, Depart. Santa Bárbara, Honduras, alt. 300^{m}, Maj. 1890, *C. Thieme*, n. 5375 ex Pl. Guat. &c., quas ed. Donn. Sm.

Solanum Sanctaeclarae Greenman (§ MEIOMERIS Dunal.).—Arbuscula parva. Rami teretes cum foliis subferruginosi stellato-

pubescentes. Folia gemina inaequalia ovata ovato-elliptica vel obovata. Inflorescentia axillaris. Flores solitarii vel gemini. Calyx urceolatus persistens. Corolla rotata glabra.

Folia gemina inaequalia utrinque sparse stellato-pubescentia subferruginosa supra atroviridia subtus pallidiora, majoribus ovatis vel ovato-ellipticis 1.2–2^{dm} longis 7–10^{cm} latis acuminatis acutis ad basin in petiolum brevem angustatis, minoribus ovatis vel subovatis subsessilibus. Flores circiter 2^{cm} longi solitarii vel gemini. Pedicelli usque ad 1^{cm} longi. Calyx urceolatus 10–12^{mm} altus latusque subtruncatus vel crenato-lobatus carnosulus et persistens extus stellato-pubescens. Corolla rotata glabra, tubo brevi quam lobi valvati circiter 3-plo breviore. Baccae maturae ignotae.—*S. synanthero* Sendt. habitu simile.

La Emilia, Llanuras de Santa Clara, Cost., alt. 250^{m}, Apr. 1896, *J. Donnell Smith*, n. 6783 ex Pl. Guat. &c., quas ed. Donn. Sm.

Solanum Tuerckheimii Greenman.—Folia alterna petiolata solitaria vel rarius gemina et maxime inaequalia oblongo-lanceolata. Flores minimi in cincinno simplice dispositi. Calyx 5–lobatus. Corolla rotata.

Frutex erectus circiter 3^{m} altus undique glaber. Folia 1–2^{dm} longa 3–7^{cm} lata breviter-acuminata obtusa vel acuta integra ad basim in petiolum sensim angustatis supra livido-viridia subtus pallidiora subcoriacea, petiolis 1–2^{cm} longis. Inflorescentia suboppositifolia 3–4^{cm} longa multiflora, pedicellis gracilibus usque ad 1.5^{cm} longis ad apicem paullo incrassatis. Calyx 1.5–2^{mm} altus persistens, lobis ovatis obtusis. Corolla rotata circiter 7^{mm} diam., lobis lanceolato-triangularibus acutis et mox recurvatis. Stamina 5 aequalia, filamentis in tubo breviter coalescentibus. Antherae 2–2.5^{mm} longae apice biporosae. Gynoecium glabrum. Bacca immatura subrotundata glabra.—*S. tristo* Jacq. habitu simile, differt foliis utrinque glabris et inflorescentia longiore et floribus minoribus. *Solano Lindenii* Rusby foliis persimilis a quo inflorescentia longiore et corolla valde minore recedit.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jul. 1903, *von Tuerckheim*, n. 8492 ex Pl. Guat. &c., quas ed. Donn. Sm.

Brachistus lanceolatus Greenman.—Caulis suffruticosus. Folia gemina inaequalia lanceolata vel ovata acuminata vel acuta ad basin in petiolum brevem attenuata. Flores axillares solitarii. Calyx breviter 5–lobatus. Corolla alba 5–lobata. Stamina corollo breviora.

Caulis teres, ramis parce pubescentibus. Folia gemina, majoribus lanceolatis 3–8.5^{cm} longis 1–2.5^{cm} latis acuminatis acutis ad basin sensim attenuatis, minoribus lanceolatis et acutis vel ovatis et obtusis. Flores circiter 1^{cm} alti

et lati axillares solitarii. Pedicelli 1.5–2.5 cm longi filiformes ad apicem incrassati primo erecti vel ascendentes deinde reflexi. Calyx corolla circiter quater brevior. Baccae globosae 7–10 mm diam. in sicco plus minusve rubrae vel flavae.— *B. diversifolio* Miers affine foliis, &c., multo recedit.

Chucaneb, Depart. Alta Verapaz, Guat., alt. 1850 m, Apr. 1889, *J. Donnell Smith*, n. 1837 ex Pl. Guat. &c., quas ed. Donn. Sm.

Coccoloba Tuerckheimii Donn. Sm. (§ PANICULATAE Meissn.).— Folia oblongo-obovata abrupte brevissimeque acuminata basi acuta supra glabra subtus puberula, ocreis amplis glabris subrhomboideis insigniter nervosis paulo infra apicem cum petiolo articulatis. Panicula sessilis, axe primario brevi, secundariis simplicibus vel prope basin furcatis, pedicellis singulis ocreola multo longioribus.

Arbor grandis speciosa. Internodia ad apicem versus ramulorum brevissima ocreis imbricantibus obtecta striata glabra. Folia 13–34 cm longa 7.5–17 cm lata, nervis lateralibus utrinsecus 10–12 ad axillas subtus fusco-barbatis, venulis minutissime anastomosantibus, petiolis striatis 1.5–3.5 cm longis, ocreis praeter marginem membranaceum 6–9 mm latum coriaceis reticulato-nervosis circiter 3 cm longis et 2.5 cm latis 6–8 mm supra articulationem petioli productis. Paniculae axis 2–4 cm longus, racemi approximati 10–15 nonnunquam prope basin semel vel bis furcati suberecti vel nutantes 18–24 cm longi folia proxima superantes 2–3 mm crassi sulcati fusco-puberuli densiflori, pedicelli 1.5–2 mm longi. Perianthium fructiferum 13 mm longum 8 mm crassum, lobis late rotundatis arcte conniventibus fructum ovalem apice obtusatum velantibus. Flores desunt.

In apricis inundatis ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350 m, Jul. 1903, *von Tuerckheim*, n. 8493 ex Pl. Guat. &c., quas ed. Donn. Sm.

Croton pyramidalis Donn. Sm. in BOT. GAZ. **35**: 7. 1903.— Diagnosi adde: Dioicus. Inflorescentia feminina masculae similis. Calycis denique retroflexi segmenta 5–6 fere sejuncta oblonga intus glabra. Disci annularis glandulae distinctae conspicuae. Ovarium longe ciliato-lepidotum.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350 m, Jul. 1903, *von Tuerckheim*, n. 8457 ex Pl. Guat. &c., quas ed. Donn. Sm.

Zebrina pendula Schnizl., var **villosa** C. B. Clarke.—Foliis subpetiolatis, elongatis, lanceolatis, in utrâque facie fulvo-villosis; inflorescentiis quasi sessilibus; filamentis glabris.

Robustior. Folia 11 cm longa, 3.5 cm lata; pili 3–4 mm longi. Calycis segmenta scarioso-brunnea apice fulvo-pilosa. Corollae tubus 5 mm longus, seg-

menta in sicco pallide coerulea laete brunneo-venosa.—Ad n. 766 *Bernoulli et Cario* accedens.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jan. 1902, *von Tuerckheim*, n. 8326 ex Pl. Guat. &c., quas ed. Donn. Sm.

Meliosma Donnellsmithii Urban.—Foliis alternis, ad apicem ramorum confertis, 3–7^{mm} longe petiolatis, obovato-oblongis, apice rotundatis, nunc brevissime acuminatis, ab $\frac{3}{4}$–$\frac{4}{5}$ longitudinis usque ad basin longe et sensim angustatis, basi ipsa abrupte in petiolum contractis v. subcordatis, 25–45^{cm} longis, 8–12^{cm} latis, cr. 3-plo longioribus quam latioribus, planis, nervo medio supra subimpresso, lateralibus supra vix prominulis v. subimpressis, subtus crassiuscule prominentibus, chartaceis v. subcoriaceis, margine integris v. superne parvissime dentatis; petalis exterioribus 2.2–2.5^{mm} longis, interioribus parce et minute pilosulis integris; cupula antherifera apice rotundata, leviter sublongitrorsum dehiscentibus; disco vix evoluto; stylo integro.

Arbuscula 3–4^{m} alta (ex *Donnell Smith*). Rami hornotini subglabri; gemmae brevissime pilosulae. Folia nervis lateralibus 15–20, subangulo 45–55° abeuntibus, utrinque reticulato-anastomosantibus, supra in sicco glauco-olivacea, subtus pallide brunnea, ad nervum medium brevissime pilosa, caeterum glabra. Paniculae cr. 6^{cm} longe pedunculatae, cr. 25^{cm} longae, ad basin glabratae, caeterum brevissime et subadpresse pilosae; bracteae triangulares v. triangulari-lanceolatae, cr. 1^{mm} longae; rami horizontaliter patentes; flores sessiles v. subsessiles, prophyllis 3–5 semiorbicularibus v. breviter orbicularibus 0.5–0.6^{mm} longis suffulti. Sepala semiorbicularia v. suborbicularia, apice rotundata, margine brevissime ciliata, 0.8^{mm} longa, 0.8–1^{mm} lata, chartacea. Petala exteriora suborbicularia coriacea, margine glabra, subinaequalia, interiora sublinearia, obtusiuscula, 1.8^{mm} longa, vix 0.5^{mm} lata, 1-nervia. Staminodia 1^{mm} longa, in $\frac{1}{5}$ alt. petalis adnata, apice truncata. Filamenta latiuscule linearia, 1.2^{mm} longa; cupula antherifera breviter, orbicularis, basi emarginata, 0.6^{mm} lata. Discus vix indicatus. Ovarium suborbiculare apice in stylum contractum. Stylus 0.8^{mm} longus, ovario duplo longior, subaequicrassus, basi oblique insertus. Stigma punctiforme.—Ambitu foliorum *M. Itatiaiae* Urb. a Brasilia valde similis.

Ad oras Río Turrialba, Prov. Cartago, Cost., alt. 500^{mm} Mart. 1896, *J. Donnell Smith*, n. 6852 ex Pl. Guat. &c., quas ed. Donn. Sm.

BALTIMORE, MD.

BRIEFER ARTICLES.

CRATERELLUS TAXOPHILUS, A NEW SPECIES OF THELEPHORACEAE.

WHILE collecting fungi on the steep bank of Fall Creek within the Cornell University campus on October 19, 1903, I found several specimens of a delicate fungus growing upon moist and very rotten leaves and twigs. Returning the next day, I found a considerable number of specimens from which a photograph (*fig. 1*) was obtained, natural size. Careful examination of the locality showed that the specimens were found only under or near the prostrate branches of *Taxus canadensis*. Continued search in all directions justified the conclusion that the fungus must depend in some manner upon the Taxus. Specimens were found under isolated Taxus plants far up the same bank, and later on the opposite side and half a mile farther up stream. In this second station also no plants were found except under Taxus branches. It then became desirable to determine, where possible, the leaves and twigs upon which the fungus had been found. The material was submitted to Mr. F. W. Foxworthy, and it was definitely determined that specimens grew on the leaves and twigs of deciduous trees as well as of Taxus and probably also of Tsuga. It is probable, therefore, that the fungus depends upon the prostrate branches of the yew for the shade and conservation of moisture which enable the delicate fleshy fruit bodies to develop. However, careful examination of the same bank where other plants furnished similarly moist conditions failed to disclose any specimens. It would seem, then, that the association of the fungus with the yew is very intimate, if not essential. It has not yet been possible to extend the search for this form into other localities where similar conditions prevail. No range, therefore, can be given. In this one locality at least one hundred and fifty specimens have been found and studied between October 19 and November 20.

Once seen, there is no great difficulty in finding the plants by close observation of the open places between the branches of yew. The most successful plan, though, is to raise the branches from the ground. The Craterellus, if present, is then conspicuous by its pure white color against the dark background of moldy leaves and twigs.

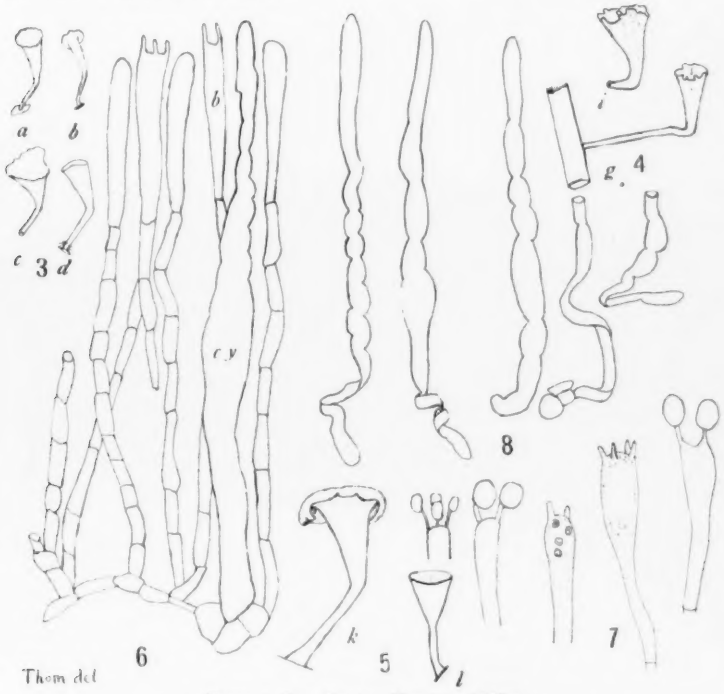
It is very commonly the only higher fungus present in those places. The plants occur singly, or sometimes in twos or threes, but never cespitose nor scarcely gregarious, since an area of two or three square rods yielded at best only about thirty specimens.

The fruit bodies when young are pure white, but as they become old the upper halves often run through shades of ochraceous, even to orange, which they retain in drying. The plants vary in height from

FIGS. 1 and 2.— *Craterellus taxophilus*. From photographs. 1, natural size; 2, ×2.5.

8 to 30 mm, and in diameter at apex, from 4 to 9 mm. One specimen was fully developed at 8 mm (*fig. 5, l*); the longest one seen (*fig. 4, g*) was 30 mm in height. Far the largest number measured between 14 and 18 mm. In shape the most usual form is an obconical pileus passing over into a stem of nearly uniform diameter and varying in length from one-half to two-thirds the whole length of the plant. The apex of the pileus is abruptly truncate at times, but is usually furnished with a free margin, which may be upturned so that the center is markedly depressed, or more commonly expanded and wavy, often deflexed in age, and even almost involute in cases (*figs. 1, 5*). The stem in some specimens is straight, but is usually curved, especially near its point of

union with the pileus (*figs. 1, 4*). Another type (*figs. 1, 2*) of general outline often occurs in which the enlargement from base of stem to apex of pileus is gradual and the curvature does not coincide with the junction of pileus and stem.



FIGS. 3–8.—*Craterellus taxophilus.*

FIG. 3.—A group of plants showing the variation in form. Natural size. FIG. 4.—*g*, the largest specimen seen, attached to a twig; and *i*, the same specimen after drying, showing the wrinkled hymenium. FIG. 5.—*k*, showing margin involute; *l*, smallest specimen, 8 mm in height, truncate at apex and without curvature. ×2. FIG. 6.—Cystidium, basidia, and subhymenial filaments shown in a crushed preparation. FIG. 7.—A group of basidia much enlarged. FIG. 8.—Different forms of cystidia.

The plants are hygrophanous when moist, and slightly viscid or glutinous when fresh. The flesh is very soft and almost waxy. The dried plants are extremely light and fragile. The stem is composed of a solid mass of more or less parallel hyphae, and expands directly to form the pileus, which is made up of very loosely woven hyphae in the

center, but becomes fairly firm in the subhymenial layers. The stem is white pruinose and bears scattered tufts of white hairs at the base (*fig. 2*).

The hymenium surrounds the upper one-third to one-half of the fruit body. It is usually smooth, but in some cases shows a tendency to the formation of longitudinal ridges. When old or dry, there are irregular longitudinal wrinkles, due perhaps to the closer texture of the surface layer compared with the very spongy substance within. These wrinkles are seen in *fig. 4, i* compared with *fig. 4, g*, which represents the same specimen when fresh. The hymenium extends to the very edge of the free margin of the pileus, where it is replaced abruptly by a loose spongy surface of mycelium. Cystidia are numerous. They are long and narrow, 60–70 × 4–6 μ, curiously swollen in part or all of their length (*fig. 8*), with often prominent curvatures at their bases where they end in the trama of the pileus. Their walls are rather thin and colorless, but they contain substances which blacken with osmic acid, especially when young. They extend but little above the surface of the hymenium, sometimes 4 μ, often less. The narrow-clavate basidia are about 18–24 μ × 4 μ. They are borne upon branching subhymenial filaments which arise with the cystidia from the trama of the pileus, and are much interwoven to form a rather compact layer (*fig. 6*, from crushed preparation). The basidia bear four sterigmata (only two and three are shown in *fig. 6*), up to 4 μ in length, with broadly elliptical to subglobose (even almost quadrate) spores 3–4 μ in diameter (*fig. 7*).

This fungus evidently belongs to the genus *Craterellus* Pers., as defined by Engler and Prantl. It is difficult to associate it closely with any of the species described on account of lack of data as to structure in most forms. I propose the name *C. taxophilus* for the species, from the habitat of the plants. The material has been referred to Professor George F. Atkinson, of Cornell University, and to Professor E. A. Burt, of Middlebury College, who agree with me in regarding the species as hitherto undescribed.

Craterellus taxophilus Thom, n. sp.— Plants scattered, rarely 2–3 together, not cespitose, on moist very rotten leaves and twigs under *Taxus canadensis*. Fruit body 8–30 ^{mm} high, mostly 14–18 ^{mm}, and 4–9 ^{mm} in diameter at apex; truncate, clavate, or obconical, tapering gradually into a stem below, or more commonly abruptly narrowed like a funnel, usually curving where hymenophore and stem unite; apex sterile, truncate, plane, or depressed, with a thin margin upturned

or expanded, even deflexed and almost involute at times, and wavy or lobed; entirely white when young, shading in age into ochraceous-buff, ochraceous, and even orange above, remaining more pallid below; hygrophanous when moist, and slightly viscid or glutinous; flesh very soft, almost of waxy consistency, composed of very loosely woven mycelium in the center, becoming denser at the surface. Stem solid, equal or slightly broadened upward, 0.5–1^{mm} in diameter, white pruinose becoming pubescent with scattered white hairs at base. The hymenium surrounds the upper two-fifths to one-half of the length of the fruit body; basidia clavate, 18–24×4μ, 4-spored, sterigmata up to 4μ in length; spores broadly elliptical to subglobose, smooth, white, 3–4μ; cystidia white, numerous, often 60–70×4–6μ, usually curved and irregularly swollen toward the base where they arise from the trama, extending beyond the basidia only when young and by 2–4μ, thin-walled and containing substances which blacken with osmic acid.

Type in Cornell University Herbarium, no. 15,445, collected from very rotten twigs and leaves of deciduous trees and conifers, but only under prostrate branches of *Taxus canadensis*, in Fall Creek gorge, Ithaca, N. Y., between October 19 and November 19, 1903.— CHARLES THOM, *Cornell University*.

NOTES ON SOUTHWESTERN AND MEXICAN PLANTS.

I. THE INDIGENOUS CENTAUREAS OF NORTH AMERICA.

THE first species of the genus Centaurea indigenous to North America was published by Nuttall in 1821, as *C. americana*. The species was originally collected in Arkansas, where it was said by Nuttall to grow "on the banks of streams, and in denudated alluvial situations, throughout the plains or prairies of the upper part of Arkansas territory."

Sprengel in the Supplement of the fourth volume of the *Systema vegetabilium* quite arbitrarily makes a new combination for Nuttall's plant, namely *C. Nuttallii*, having himself previously, in the third volume of the *Systema*, p. 407 (1826), used the combination *C. americana* for a Peruvian plant, which is very different from the North American species. Further, in 1831, D. Don, in Sweet's *British flower garden* **2**: *pl. 51*, characterizes and illustrates the species published by Nuttall under the name *Plectocephalus americanus*. Both of these combinations, *C. Nuttallii* and *Plectocephalus americanus*, are merely altered names for Nuttall's species and are invalidated by all present rules of

nomenclature. In 1837 DeCandolle published *C. mexicana*, based upon Berlandier's nos. 430 and 1750, collected between Bexar and the Trinity River, Texas. Later, *C. mexicana* was shown to be identical with *C. americana* Nutt.

A careful study of a large suite of specimens in the Gray Herbarium shows very clearly that we have at least two indigenous species of this genus in the southwest, one of which is new to science, and is readily separated from the older species on the involucral characters alone; its distribution, moreover, is more western and southern, and it grows at a higher altitude. *C. americana* has been so well described and illustrated that it is unnecessary to present here more than the literature and the citation of specimens. Of its congener, however, a description is given below. The two indigenous North American species as here recognized by the writer are as follows:

*Involucral bracts stramineous or the inner ones slightly purplish, pectinate with 3–8 pairs of lateral firm teeth.

C. AMERICANA Nutt. Jour. Acad. Phil. **2**: 117. 1821; Bart. Fl. Am. Sept. **2**: *pl. 50.* 1822; Colla, Hort. Ripul. App. i. 119. *pl. 6.* 1827; Reichb. Ic. Exot. **2**: *pl. 132.* 1828; DC. Prodr. **6**: 575. 1837; Torr. & Gray, Fl. N. Am. **2**: 453. 1843; Engelm. & Gray, Pl. Lindl. 14. 1845; Fl. Serres **4**: *pl. 327.* 1848; Gray, Pl. Wright. **1**: 125. 1852; Young, Fl. Texas 361. 1873; Meehan's Nat. Fls. II. **2**: *pl. 17.* 1880; Hemsl. Biol. Cent. Am. Bot. **2**: 253. 1881 in part, *i. e.*, excl. pl. Rothrock; Gray, Syn. Fl. **1**[2]: 407. 1886; Coulter, Contrib. U. S. Nat. Herb. **2**: 244. 1891–94; Small, Fl. Southeastern U. S. 1308. 1903.—*C. Nuttallii* Spreng Syst. **4**: (Suppl.) 298. 1827.—*C. mexicana* DC. Prodr. **6**: 575. 1837.—*Plectocephalus americanus* Don in Sweet's Brit. Fl. Gard. **2**: *pl. 51.* 1831; Spach, Hist. Veg. **10**: 63.

UNITED STATES. Arkansas: specimen *ex hb. Durand.* Louisiana: *Dr. Leavenworth.* Texas: *Pope; Lindheimer*, nos. 114, 34; dry prairies, near Dallas, *Hall*, no. 373, *Reverchon; Drummond*, no. 169; between Bexar and the Trinity River, *Berlandier*, nos. 430, 1750; Kerrville, altitude 490 to 615[m], *Heller*, no. 1774; Weatherford, *Tracy*, no. 7896. New Mexico: Jornado del Muesto, *Dr. Wislizenus;* exp. from western Texas to El Paso, *Wright*, no. 405; White Mountains, altitude 1850[m], *Wooton*, no. 195. MEXICO. Coahuila: Saltillo, *Dr. Edward Palmer*, nos. 766 (coll. of 1880), 294 (coll. of 1898) white-flowered form. Chihuahua: Bachimbo Cañon, *Pringle;* Rio Sta Maria, *Thurber*, no. 748.

** Involucral bracts greenish or stramineous below, conspicuously tipped with chestnut-brown, pectinate-fimbriate with 8–12 pairs of lateral rather slender teeth.

C. Rothrockii Greenman, n. sp. Annual or biennial (?), 3–10 ^{dm} high: stem erect, simple below, sparingly branched above, sulcate-striate, glabrous or slightly hirtellous; leaves lanceolate to oblong-lanceolate, 3–12 ^{cm} long, 1–3.5 ^{cm} broad, sessile and often semiamplexicaul, acuminate, acute, sometimes terminated by a conspicuous mucro, entire to slightly sinuate-dentate, hirtellous-puberulent on both surfaces, hispidulous on the margins, resiniferous-dotted; the uppermost leaves much reduced and not infrequently subfimbriate near the tip: peduncles thickened above: heads large, 3–5 ^{cm} high, including the rays 3–15 ^{cm} in diameter: involucre subcampanulate, in well-developed specimens about 3 ^{cm} high and 4 ^{cm} broad; bracts of the involucre about 9-seriate, rather closely imbricated, lanceolate, pectinate-fimbriate in the upper third, bearing 8–12 pairs of brownish ciliated rather slender teeth: the neutral marginal flowers (rays) elongated, conspicuous, usually purple, much exceeding the lemon-yellow flowers of the disk: mature achenes oblong-obovate, 5 ^{mm} long, black and smooth.—*C. americana* Rothrock in Wheeler's Report 180. 1878, not Nutt.—*Centaurea* sp. Engelm. in Wislizenus Report 107. 1848, Reprint 23. UNITED STATES. Arizona: Chiricahua, *Rothrock*, no. 527 (type). MEXICO. Chihuahua: near Colonia Garcia, altitude 2300 ^{m}, August 9, 1899, *Townsend & Barber*, no. 247: August 1–20, 1899, *E. W. Nelson*, no. 6175; southeastern Chihuahua, August–November 1885, *Dr. Edward Palmer*, no. 415; Llanos, *Dr. Wislizenus*. Durango: Sierra Madre, 18.5 ^{km} north of Guaucevi, altitude 2460–2770 ^{m}, August 18, 1898, *E. W. Nelson*, no. 4774. Zacatecas: between Bolaños and Guadalajara, September 20, 1897, *Dr. J. N. Rose*, no. 3033. Oaxaca: La Mixteca, Huauclilla, District of Nochixtlan, altitude 2000 ^{m}, June 26, 1898, *F. Lopez* (*Conzatti & González*, no. 781).

These two species are among the most attractive of the genus; both are well worthy of garden cultivation. *C. Rothrockii* is equal, if not superior, to its sister species *C. americana*, which has already found its way to many American gardens. The writer takes pleasure in dedicating the handsome species here described to Dr. Joseph Trimble Rothrock, now of the State Forestry Commission of Pennsylvania.

II. ON THE GENUS ASPILIOPSIS.

In the "Supplementary leaflet" to the *Contributions from the Gray Herbarium of Harvard University* new series, no. xxv, issued September

25, 1903, the writer proposed the name *Aspiliopsis* for the plant described in the body of the same contribution, p. 106, as *Altamirania*, n. gen. of Verbesineae (Compositae). Professor Theo. D. A. Cockerell, of Colorado Springs, has most courteously called my attention to the fact that no binomial was given under *Aspiliopsis*. This may be formed as follows: **Aspiliopsis pachyphylla**, n. comb. *Altamirania pachyphylla* Greenm. Proc. Am. Acad. **39**: 106. 1903.—J. M. GREENMAN, *Gray Herbarium, Cambridge, Mass.*

VITALITY OF SEEDS.

THE statement in the GAZETTE for February by J. W. T. Duvel concerning the preservation of seeds buried in the soil reminds me of some tests I made years ago, reporting the results in the *Proceedings* of the Society for the Promotion of Agricultural Science for 1894. In September 1882 I gathered and shelled 50 heads of red clover from each of five plants, and kept them in two-ounce bottles, each lot by itself. On June 7, 1894, I tested 50 seeds of each for vitality, and again on June 23, 1894, I tested another set of 50 seeds each. The average of the two lots of all seeds was 35.8 per cent. of living seeds. Of the hundred taken from one of the bottles 66 seeds germinated; while of those from another bottle only 4 seeds out of the hundred germinated. In these cases some of the seeds of each lot retained vitality for nearly twelve years.

In the *Proceedings* of the same society for 1899, I reported the results of tests of the vitality of seeds of weeds buried by me in "clean" dirt in bottles for twenty years. The seeds germinated very unevenly. I name the species of seeds of which some germinated: Amaranthus retroflexus, Brassica nigra, Capsella Bursa-pastoris, Lepidium virginicum, Anthemis cotula, Malva rotundifolia, Oenothera biennis, Polygonum hydropiper, Portulaca oleracea, Rumex crispus, Stellaria media, Verbascum thapsus. None of the following germinated: Ambrosia artemisiaefolia, Erechthites hieracifolia, Euphorbia maculata, Plantago major, Setaria glauca, Trifolium repens, Bromus secalinus, Lychnis githago. I give the names of seeds by which they were known when buried; at the time of their resurrection the names of some of them had been changed!—W. J. BEAL, *Agricultural College, Michigan.*

CURRENT LITERATURE.

BOOK REVIEWS.

The culture of plant rusts.

THE ALTERNATION of wholly unlike forms in many Uredineae, the aecidium on the one hand, and the uredo- and teleutospores on the other, and especially the occurrence of these forms upon unrelated hosts in the heteræcismal species, has given to the study of the rusts by the culture method a most absorbing interest. No law has been detected governing the selection of alternate hosts by the different species of rusts, and so each new instance brought to light is an independent discovery, worked out with little or no aid from previous records. As the work progresses, the number of possible combinations between known forms necessarily diminishes, but new forms are found, and known forms are divided up by previously undetected characters

The study of rusts by cultures began in 1865, and has been especially active during the last decade. The results have opened up many intricate problems, none of which has been more discussed and seemed more weighty than that of the relationship of what have been called physiological species or races. The literature of the subject has become abundant and widely scattered, until even a specialist finds it difficult to follow.

The need of a work in which the results thus far attained by culture methods are collected, arranged, and summarized is a real need, and one which has been happily met by Dr. H. Klebahn,[1] of Hamburg, in a treatise on the heteroecismal rust-fungi.

Although it has taken nearly 450 large octavo pages in which to present the subject, the work could not be surpassed for concise and lucid treatment, and for completeness without redundancy. It is an admirable account of the subject.

The author begins his treatise with a short account of other organisms, both animal and plant, that possess heteroecismal adaptations, and then takes up the history of the knowledge of the heteroecismal rusts. In the pages that follow the natural distribution of the aecidiospores, uredospores, and sporidia are discussed, and the methods of natural infection. All available information is presented regarding such questions as: Can the uredo and teleutosporic generation of heteroecismal rusts arise from sporidia, and can aecidia of heteroecismal rusts arise in any other way than from sporidia? These are the questions of much economic interest.

[1] KLEBAHN, H., Die wirtswechselnden Rostpilze. 8vo. pp. xxxvii + 447. Berlin: Gebrüder Borntraeger. 1904. *M* 20.

Naturally the great problems of the cereal rusts receive considerable attention. Regarding the continuation of the rust through the agency of the seed, and Eriksson's "mycoplasm" theory, the arguments are fully presented, but the author regards these assumptions far from proved.

The chapter upon methods of investigation is especially interesting and helpful. No one has done more or better work in this line of research than the author, and he speaks with long experience and wide knowledge. Sixteen pages are devoted to the study of rust problems from the point of view of plant geography, a subject that will grow more and more important as fuller data become available. In taking up the matter of the association of the host plants selected by the aecidial and teleutosporic generations, the author has developed a number of exceedingly ingenious and helpful charts.

The seventy-five pages remaining of the first half of the book are devoted to the absorbing and intricate problems presented by specialization, the limitations of species and races, the origin of heteroecism, and the questions of sexuality. The numerous theories and facts are clearly and ably presented, but one must confess a feeling of disappointment that, after mastering present knowledge and canvassing the views of other writers, no substantial advance is made in formulating an explanation of the problems. It is evident that these questions must await the writer who is a philosopher as well as a scholar.

The second half of the volume is devoted to a detailed account of the 150 or more species that have been studied by cultural methods. An index of species, one of hosts, and a full bibliography complete one of the most important contributions to the study of plant rusts ever published. — J. C. ARTHUR.

Physical chemistry.

STUDENTS and research workers in plant as well as in animal physiology will find Fischer's translation of Cohen's *Physical Chemistry*[2] an almost indispensable book. This treatise presents those considerations of the general subject which have a close bearing upon physiological phenomena, and presents them in a concise, clear, readable form, with only as much mathematics as is necessary for the establishment of the principles. Besides pure physical chemistry, the book contains a discussion of a number of applications of this science in hygiene, pharmacology, physiology, etc.—discussions which should be eye-openers to many a student of biology. The subject-matter is divided into seventeen lectures, which are numbered serially. A statement of their titles is given here to show the scope of the book: Reaction velocity; Inversion of cane sugar and catalysis in general; The action of ferments; Temperature and reaction velocity; Equilibrium (three lectures); The friction of liquids; Osmotic pressure; The determination of the molecular weight of dissolved substances; The theory of electrolytic dissocia-

[2] COHEN, ERNST, Physical chemistry for physicians and biologists, translated by Martin H. Fischer. pp. viii + 343. *figs. 49.* New York: Henry Holt & Co. 1903.

tion (two lectures), and its applications (three lectures); and Electromotive force (two lectures). References to important papers are given by footnotes. At the end of the volume is an index both of subjects and of authors' names, but we look in vain for a table of contents to aid the reader in following the scheme of presentation. The translation is excellent throughout, and well worthy of the accuracy of the original.—B. E. LIVINGSTON.

A premedical text-book.

THIS GENERAL TEXT-BOOK of botany[3] is written for premedical and pharmaceutical students in particular and the nonprofessional undergraduate incidentally. Like most German works of its sort, it is divided into three parts: first, a general treatment of the organogeny and cell structure of plants; second, their physiology; third, the general morphology of representatives of the great plant groups. Of these three, the greatest stress is laid upon the first part, which reflects in great measure the views of Goebel as found in his *Organographie* in much detail. The chapters treating of respiration, photosynthesis, and other plant functions are much more elementary, as is the general morphology. There is a wholesome admixture of new illustrations with the time-worn veterans that the author apparently hadn't the heart or the courage to drop by the wayside. In the treatment of what the author calls the "Spezielle Botanik" there is no description nor figure of the sex organs of the liverworts or mosses, and none of the sexual generation of the water ferns, equisetum, selaginella, isoetes, gymnosperms, and angiosperms. The groups of flowering plants described seem to have been selected largely because members of the order afford commercial products. The stamens and pistils are referred to as "geschlechtsorgane." This is an anachronism that does not accord with the views expressed on the alternation of generations, which are quite up to date.—FLORENCE M. LYON.

MINOR NOTICES.

THE FLORA OF PENNSYLVANIA, in preparation many years by the late Professor Thomas C. Porter, has appeared under the editorship of Dr. John K. Small.[4] It consists of a list of gymnosperms and angiosperms with stations, and is the result of personal exploration and extensive cooperation of others for a period of over sixty years. Professor Porter's ambition was to make his list of Pennsylvania plants complete, and this led him to defer printing it from time to time. When death overtook him in his eightieth year, the work seemed to him not yet perfect enough for publication, but a provision in his will for its publication has enabled Dr. Small to present it to the public. The summary shows that it records 2201 species, which have

[3] GIESENHAGEN, K., Lehrbuch der Botanik. Imp. 8 vo. pp. xii + 475. *figs.* 557. Stuttgart: Fr. Grub. 1903.

[4] PORTER, THOMAS CONRAD, Flora of Pennsylvania. Edited with the addition of analytical keys by John K. Small. 8vo. xv + 362. Boston: Ginn & Co. 1903. $2.15.

been brought together with more painstaking care, probably, than has ever been used in the preparation of a catalogue of plants.—J. M. C.

A SECOND EDITION of Professor Atkinson's book on *Mushrooms* appeared recently from the press of Henry Holt & Company.[5] The new volume contains ten illustrations which did not appear in the first edition. The value and attractiveness of the work are further enhanced by a chapter on the cultivation of mushrooms, illustrated by half-tones of mushroom houses and flash-light photographs of mushroom beds in abandoned mines in New York and Pennsylvania. This chapter gives a good account of the status in the United States of an industry of whose existence probably few are aware. Methods of culture and marketing mushrooms are fully discussed in this chapter.

The typography and half-tone work of this edition are of the same excellent character as in the first edition, making it an exceedingly attractive work. —H. HASSELBRING.

THE SIXTH FASCICLE of Engler's great work on the genera and families of African plants was published in the spring of 1901, and just now, nearly three years later, the seventh fascicle[6] has made its appearance. It is a presentation of the genus Strophanthus (Apocynaceae) by E. Gilg, who recognizes 43 species, only one of which is new, but 8 of which are of recent publication by the author. The 10 lithographic plates, one of them colored, are models of illustrative work.—J. M. C.

NOTES FOR STUDENTS.

DIXON has examined the temperature difference between subterranean organs and the soil by a special thermopile.[7] He finds generally no higher temperatures than those of the soil and no diurnal periodicity other than is induced by periodic fluctuations of external temperatures. The adaptation of apparatus and discussion of errors in thermoelectric measurement of temperatures have a positive value.—C. R. B.

BOUILHAC AND GIUSTINIANI[8] believe that mixtures of bacteria with such algae as Nostoc and Anabaena will prove of great economic value in soils that are poor in nitrogen. Cultures of buckwheat supplied with these forms developed normally in soils deprived of all other organic matter, and subsequent tests showed that large quantities of nitrogen had been fixed. The control cultures of buckwheat developed poorly.—H. C. COWLES.

[5] ATKINSON, G. F., Studies of American fungi. Imp. 8vo. pp. vii + 323. *figs. 230*. New York: Henry Holt & Co. 1903. $3.

[6] ENGLER, A., Monographieen afrikanischer Pflanzen-Familien und -Gattungen. VII. Strophanthus, bearbeitet von E. Gilg. 4to. pp. 48. *pls. 10*. Leipzig: Wilhelm Engelmann. 1903. *M* 16.

[7] DIXON, H. H., Observations on the temperature of the subterranean organs of plants. Trans. Roy. Irish Acad. **32B**: 145–170. *pls. 5–8*. 1903.

[8] BOUILHAC and GIUSTINIANI, Sur une culture de Sarrasin en présence d'un mélange d'algues et de bactéries. Compt. Rend. **137**: 1274–1276. 1903.

MISS EDITH CHICK[9] has had an opportunity to examine a few seedlings of the Californian species of Torreya, a genus of the Taxaceae of special interest to the morphologist and of peculiar inaccessibility. The meager results confirm the preconceived opinions as to the primitive character of the genus. In the cotyledons there is such a primitive character as the presence of centripetal wood, while the lobing and adhesion of the cotyledons is a feature shared with such genera as Ginkgo and Zamia.— J. M. C.

IN A BULLETIN of the North Carolina Agricultural Experiment Station, Stevens and Sackett[10] describe a new wilt disease of the tobacco which has caused much damage in Granville county. Happily it is yet rather local, but it seems to be spreading. It appears to be due to bacteria which plug the tracheids and blacken the xylem, infection seeming to come through the roots. The disease becomes more and more intense with each crop and will necessitate the abandonment of affected fields unless means of prevention can be found or an immune race can be bred.— C. R. B.

ARBER[11] has presented to the Geological Society of London a paper describing the flora of the Cumberland coal-field. He enumerates twenty species from the Sandstone series and twenty-two from the productive measures. The lower beds of the Sandstone series are held to belong to the middle coal measures and the upper to the Transition coal measures. The productive measures are considered as of middle coal-measures age, the paleobotanical evidence for this conclusion being substantiated by the molluscan remains in the overlying strata. The paper, while describing no new species, is an admirable contribution to local stratigraphy. It is illustrated by two plates of the more interesting species and concludes with a brief bibliography.—E. W. BERRY.

ZELENY[12] has investigated the changes which take place in the position and size of leaflets of palmately compound leaves when one lateral leaflet is removed as early as possible. The remaining leaflets tend to form a new symmetrical system having one less member. This is attained chiefly by the movement of those leaflets which are left in an asymmetrical position with reference to the petiole. In *Lupinus albus* there was a frequent rotation of the leaf which placed the petiole in an interval different from that occupied by it when the operation was performed. Comparison of these leaves with the

[9] CHICK, EDITH, The seedling of *Torreya myristica*. New Phytologist **2**: 83–91, *pls. 7–8*. 1903.

[10] STEVENS, F. L., and SACKETT, W. G., The Granville tobacco wilt; a preliminary bulletin. Bull. 188, N. C. Agr. Exp. Sta. 1903.

[11] ARBER, E. A. N., Fossil flora of the Cumberland coal-field and the paleobotanical evidence with regard to the age of the beds. Quart. Jour. Geol. Soc. Lond. **59**: 1–24. *pls. 1, 2*. 1903.

[12] ZELENY, CHARLES, The dimensional relations of the members of compound leaves. Bull. N. Y. Bot. Garden **3**: 134–174. *figs. 13*. 1903.

normal showed that presence of the petiole between any two leaflets serves to widen the normal interval by about 37°. The leaflets of the leaves operated on were in each instance shorter than those of the normal leaves.—G. H. SHULL.

REINKE DISCUSSES the available sources of nitrogen for algae, especially marine forms, and concludes that those which he and others have named heretofore, particularly the additions from the offal of cities, are entirely inadequate.[13] In Kiel harbor, nitrogen bacteria (*i. e.*, species capable of fixing free N dissolved from the air) have been found, notably *Clostridium Pasteurianum* and *Azotobacter Chroococcum*, both in the mud at the bottom and in the mucilage covering the fronds of Laminaria, etc. Indeed, the latter are like agar plate-cultures of such species. Reinke suggests, therefore, that this is a sort of symbiosis, inevitably recalling the association of Rhizobia with Leguminosae, in which the bacteria get carbohydrates from the algae and give them nitrogenous compounds produced by the fixation of free N.—C. R. B.

J. ERIKSSON[14] has pointed out that Professor Marshall Ward's attack upon his mycoplasm hypothesis does not distinguish between the two essential points involved. The first is the existence of an internal germ of disease; the second the form in which such an internal germ may be conceived of as existing. The former point Eriksson would regard as proved, the latter as purely hypothetical; and hence he sees no reason why rejection of the latter should involve repudiation of the former. He calls attention to the fact that Professor Ward's work was carried on with artificial infections, when the whole theory rests upon outbreaks of the disease which cannot be explained by external infection; the theory having to do with that may be called the first stage of the disease, and Professor Ward's experiments with the second stage.—J. M. C.

N. BERNARD has discovered some interesting peculiarities about the germination of orchids.[15] Seeds of Cattleya and Laelia germinate readily in about fifteen days, soon developing into minute green spherules. The plants rest here for some time and later slowly develop into a top-shaped body, which is always infested at the suspensor end by an endophytic fungus. In aseptic cultures the seedling does not go beyond the spherule stage, whence Bernard concludes that fungi are necessary even in the early stages of the orchid plant. By introducing the proper fungi, the ordinary slow growth may be much accelerated, and the resting period after the spherule stage may be much

[13] REINKE, J., Zur Ernährung der Meeres-Organismen disponiblen Quellen an Stickstoff. Ber. Deutsch. Bot. Gesells. **21**: 371–380. 1903.

[14] ERIKSSON, J., The researches of Professor H. Marshall Ward on the brown rust on the bromes and the mycoplasm hypothesis. Arkiv för Botanik **1**: 139–146. 1903.

[15] BERNARD, N., La germination des Orchidées. Compt. Rend. **137**: 483–485. 1903.

abbreviated. The author concludes by stating that we have here an embryo which cannot develop without fungal symbiosis, just as an egg commonly has to be fertilized before it can develop.— H. C. COWLES.

A PAPER BY HELLER[16] on the influence of ethereal oils and the like upon plants comes from the Leipzig laboratory. Plants were subjected to the influence of such substances as the oils of Eucalyptus, Citrus, Salvia, Thymus, Origanum, Mentha, Pinus, etc., and of gum camphor, thymol, etc., as well as of petroleum ether, petroleum, benzine, benzene, xylene, anilin, phenol, etc. These substances are more poisonous in vapor form than as liquids or in aqueous solution. Plants which produce an oil are somewhat immune to its action. Volatile hydrocarbons act like ethereal oils. As would be expected, all these substances enter the cell by going into solution in the water of imbibition of the cell walls and then diffusing as solutes. But, as would not be expected, a dry membrane appears to be a poorer protection to the plant than a moist one. Resin and paraffin failed to gain an entrance into the cells.— B. E. LIVINGSTON.

DIXON has replied to criticisms of the cohesion theory of the ascent of water[17] by Steinbrinck and by Copeland. To Steinbrinck's contention that the permeability of lignified walls to air renders the Dixon-Joly theory untenable, he replies briefly that the gas is chiefly in solution, in which state, as had already been shown, it does not interfere with the transmission of tensions in water columns. Furthermore, even if the gas is free it only interrupts the function of the vessel in which it develops. Chief attention is given to Copeland,[18] whose methods and interpretations are criticized. Dixon holds that the manometers as arranged in Copeland's apparatus indicate only local differences of gas pressure and of water pressure, the latter produced by long continued absorption of water after the plaster has set. This peculiarity of plaster may be a source of error in Copeland's work; the other criticisms do not appear valid to one familiar with his experimentation.—C. R. B.

THE POLLEN TUBE structures of *Cupressus Goveniana*, as recently described by Juel,[19] are extremely interesting. Up to the division of the body cell, the sequence is as in other members of the Cupresseae, there being a stalk nucleus, a tube nucleus, and a body cell. The body cell, however, instead of giving rise to two sperm cells, gives rise to a cell complex consisting of a variable number of cells, sometimes four, oftener eight or ten,

[16] HELLER, A. Ueber die Wirkung ätherischer Öle und einiger verwandter Körper auf die Pflanzen. Flora **93**: 1–31. 1903.

[17] DIXON, H. H., The cohesion theory of the ascent of sap. Sci. Proc. Roy. Dublin Soc. **10**¹: 48–61. 1903.

[18] COPELAND, E. B., The rise of the transpiration stream: A historical and critical discussion. BOT. GAZ. **34**: 161–193, 260–283. 1902.

[19] JUEL, H. O., Ueber den Pollenschlauch von Cupressus. Flora **93**: 56–62. *pl. 3.* 1904.

and in a few very vigorous tubes about twenty. All other living gymnosperms yet described have but two sperm cells. The pollen grains of Cordaites contain a cell complex which has been interpreted as an antheridium. The cell complex in Cupressus seems to be similar, although in Cordaites it is formed in the pollen grain, while in Cupressus is formed later in the pollen tube. *Callitris quadrivalvis* was also examined, but the pollen tube structures are practically the same as described by Belajeff for Juniperus and by Land for Thuja.—C. J. CHAMBERLAIN.

ZEILLER AND FLICHE[20] have discovered fossil remains of Sequoia in Portlandian beds near Boulogne-sur-Mer. This is a discovery of great importance, since Sequoia has not previously been reported from Jurassic strata. Even at this early date the generic characters were well marked, and some of the specific characters of *Sequoia gigantea* were present. Of no less importance is the finding of Pinus in the same beds, one of the Strobus type, and one more like *P. Laricio*. Pinus is thus surely established as a Jurassic genus, and largely differentiated as now. Although Jurassic pines have been reported at least three times in as many places, not till now has there been such undoubted evidence. Perhaps most remarkable of all is the fact that this oldest of known pines is in no sense generalized or archaic, but belongs to the most highly specialized group of pines as they exist today. Thus in the pines, as in so many plants and animals, are the first known forms as highly specialized as any which come later.—H. C. COWLES.

MATHEWS[21] has hit upon what seems to be a generalization of rather broad significance in his work upon the toxic action of ions upon eggs of Fundulus. Since this may well apply to plant protoplasm as well as to that of animals, it would be well for plant physiologists who are working with poisons to be familiar with it. The hypothesis is briefly this: The physiological action of both kations and anions is an inverse function of their solution tension, *i. e.*, their affinity for their electric charge. Thus "mercury, silver, and copper are poisonous because they part with their charges to the protoplasmic particles easily, thereby bringing about changes in the state of aggregation of the colloidal particles, and decomposition of the molecules." The physiological action of a salt is, therefore, an inverse function of the sum of the solution tension of its resulting ions. There seems also to be an inverse relationship between atomic volume and toxicity, and a direct relation between this and equivalent weight. Poisonous action of metals would thus appear to be a "periodic function of their atomic weights." While the evidence is fairly in unison, the hypothesis must needs be tested much further before it is fully established.—B. E. LIVINGSTON.

[20] ZEILLER, R., and FLICHE, P., Découverte de strobiles de Sequoia et de Pin dans le Portlandien des environs de Boulogne-sur-Mer. Compt. Rend. **137**: 1020–1022. 1903.

[21] MATHEWS, A. P., The relation between solution tension, atomic volume, and the physiological action of the elements. Am. Jour. Physiol. **10**: 290–323. 1904.

ACCORDING TO Molliard and Coupin[22] the sterigmata and basidia of *Sterigmatocystis nigra*, when grown in a medium without potassium, have a remarkable tendency to grow out into mycelial filaments instead of producing conidia in the normal way. These filaments sometimes enlarge to form secondary conidial heads, which in turn may proliferate again. Finally some conidia are produced, but of smaller size and with thinner walls than normally occurs. Often these conidia appear on the ends of simple radiating branches without a central head, somewhat after the manner of Penicillium; or the swollen head may be produced with its basidia, which bear conidia directly without the intervention of sterigmata at all, somewhat as in Aspergillus. Conidia which germinate in absence of potassium are apt to produce chlamydospores very soon, sometimes immediately upon germination. The control cultures, wherein the fungus grows normally, differ from those which exhibit the above phenomena only in the presence of 0.6 gm of K_2CO_3 in 1500 cc of medium. Both control and experiment cultures contain 0.4 gm of $MgCO_3$, so it is hardly possible that the response is due to the anion CO_3. The difference in osmotic pressure between the two is so slight as to be negligible. The last two points are not considered by the authors.—B. E. LIVINGSTON.

IN A SERIES of digestion experiments upon the mannans and galactans of certain leguminous and other seeds and of the tubers of several orchids, Hérissey has demonstrated a new enzyme, or group of such bodies, which he terms seminase.[23] Seminase is a soluble ferment, best obtainable from alfalfa (lucerne), but it has been found in *Aspergillus niger* and to some extent in the tubers of certain Orchidaceae. It has the power to render soluble both mannans and galactans, producing mannose and galactose, respectively. Alfalfa seeds which have been germinated at a temperature of 27–30° C. for from 36 to 48 hours yield the maximum amount of the ferment. The body obtained from these seeds acts upon the carbohydrates of other seeds, upon those of orchid tubers, etc., but fails to have any effect upon those of palm seeds, although the latter yield mannose when hydrolyzed with weak mineral acid. Although the seeds of alfalfa, etc., even in the resting state, contain seminase, yet at no stage of their germination has the author found mannose or galactose present in quantity sufficient for identification. Cane sugar is generally present, however, and the author believes that mannose and galactose are only a transition state, and that these bodies pass as soon as formed into some other carbohydrate, perhaps cane sugar.—B. E. LIVINGSTON.

[22] MOLLIARD, M., and COUPIN, H., Influence du potassium sur la morphologie du *Sterigmatocystis nigra*. Rev. Gén. Bot. **15**:401–405. *pl. 17*. 1903.

[23] HÉRISSEY, H., Recherches chimiques et physiologiques sur la digestion des mannanes et des galactanes, par seminase, chez les végétaux. Rev. Gén. Bot. **15**: 345–368, 406–417, 446–463. 1903.

DOUGLAS H. CAMPBELL[24] has published a second paper upon the Araceae, dealing chiefly with *Aglaonema commutatum* and *Spathicarpa sagittaefolia*. In the former species the embryo-sacs vary in number from one to three, and where two or three are formed they may be derived from a single archesporial cell or may possibly originate independently from hypodermal cells. The most interesting feature, however, is the variation in the number of nuclei in the embryo-sac, this ranging from four to twelve and with slight indication of polarity. Multiple nuclear-fusions are of common occurrence, and it is often impossible to be certain which of the structures represent the egg-apparatus and which the antipodal cells. The embryo of this species also conforms to what seems to be an aroid type, namely a large mass of cells with little differentiation of external parts and with tissues almost completely homogeneous.

In Spathicarpa the embryo-sac is of the ordinary angiospermous type, but after fertilization the antipodals become greatly enlarged and one of them may divide. The embryo remains small and the external organs are evident, but the tissues are only slightly developed.

In both species the development of endosperm proceeds gradually from the base of the embryo-sac until it is completely filled.—J. M. C.

DEANE B. SWINGLE[25] in his study of the formation of spores in Rhizopus and Phycomyces has summarized the essential features of the process as follows: (1) streaming of the cytoplasm, nuclei, and vacuoles up the sporangiophore and out toward the periphery, forming a dense layer next the sporangium wall and a less dense region in the interior, both containing nuclei; (2) formation of a layer of comparatively large, round vacuoles in the denser plasm parallel to its inner surface; (3) extension of these vacuoles by flattening so that they fuse to form a curved cleft in the denser plasm; and, in the case of Rhizopus, the cutting upward of a circular surface furrow from the base of the sporangium to meet the cleft formed by these vacuoles, thus cleaving out the columella; (4) division of the spore-plasm into spores; in Rhizopus, by furrows pushing progressively inward from the surface, and outward from the columella cleft, both systems branching, curving, and intersecting to form multinucleated bits of protoplasm, surrounded only by plasma-membranes and separated by spaces filled with cell sap only; in Phycomyces, by angles forming in certain vacuoles containing a stainable substance and continuing outward into the spore-plasm as furrows, aided by other furrows from the columella cleft, and dividing the protoplasm into bits homologous with and similar to those in Rhizopus, and separated by furrows

[24] CAMPBELL, DOUGLAS H. Studies on the Araceae. The embryo-sac and embryo of Aglaonema and Spathicarpa. Ann. Botany **17**: 665–687. *pls. 30–32.* 1903.

[25] SWINGLE, DEANE B., Formation of the spores in the sporangia of *Rhizopus nigricans* and of *Phycomyces nitens.* pp. 40. *pls. 6.* Bulletin 37, Bureau of Plant Industry. 1903.

partly filled with the contents of the vacuoles that assist in the cleavage; (5) formation of walls about the spores and columella, and, in the case of Rhizopus, the secretion of an intersporal slime; (6) partial disintegration of the nuclei in the columella.—J. M. C.

WHAT SEEMS a careful study of the effect of certain external conditions upon the evolution of oxygen by some green water plants has been made by Pantanelli.[26] He finds that the curve of oxygen production with varying light intensity shows a distinct optimum (at about one-fourth the intensity of direct sunlight), beyond which it falls as light increases, unless the supply of CO_2 is varied at the same time, in which case the optimum would be displaced in the direction of weaker light with less CO_2, and toward the stronger light with more CO_2. The regulation of the activity of the chloroplasts is not instantaneous, five to ten minutes passing before a change in their activity can be ascertained. Ultra-optimal light stops protoplasmic streaming, and, if excessive, produces aggregation and diminishes the evolution of O_2. Furthermore, and independently of these changes, it produces in the chloroplasts phenomena of fatigue like those of an isolated muscle, which pass away gradually after the return of normal conditions, the slower the more complete the fatigue. By light intense enough to diminish the decomposition of CO_2 the chlorophyll pigment is attacked. After such injury it is never reformed. The evolution of O_2 increases with the increased content of CO_2 in the water to an optimum, and then decreases, unless the light varies correspondingly. The bubbles of gas given off, however, continue to increase beyond the CO_2-optimum, but contain more and more CO_2, which merely diffuses through the plant unchanged.

Pantanelli also finds that various solutes exercise a marked influence upon photosynthesis, for which details the original must be consulted. He holds the chief result of his work to be the demonstration that the plasmatic portion of the chloroplasts works, tires, and recuperates, the chlorophyll remaining primarily wholly indifferent; but if the plasmatic stroma becomes injured, the chlorophyll immediately suffers photochemical oxidation. Normally, however, its lability does not appear, because it is constantly protected by the plasma. Nothing, he thinks, indicates that in strong light chlorophyll is continually decomposed and regenerated—an assumption of those who look upon chlorophyll as a sensitizer.—C. R. B.

ITEMS OF TAXONOMIC INTEREST are as follows: G. F. ATKINSON (Ann. Mycol. **1**: 479–502. *pl. 10.* 1903) has discussed the genus Harpochytrium in the United States.—F. v. HÖHNEL (*idem* 522–534) has described the following new genera of fungi: *Bresadolella* (Nectriaceae), *Myxolibertella* (Melanconieae), *Sporodiniopsis* (Hyphomycete), *Cirrhomyces* (Dematieae), *Aegeritopsis* (Tuberculariеae).—R. PILGER (Engler's Pflanzenreich IV. 5. p. 117.

[26] PANTANELLI, ENRICO, Abhängigheit der Sauerstoffausscheidung belichteter Pflanzen von äusseren Bedingungen. Jahrb. Wiss. Bot. **39**: 167–228. 1903.

1903) has described a new genus (*Acmopyle*) of Taxaceae. — C. S. SARGENT (Proc. Rochester Acad. Sci. **4**: 93–106. 1903), in a presentation of the genus Crataegus as displayed in and about Rochester, N. Y., has described 27 new species. — W. R. MAXON (Contrib. U. S. Nat. Herb. **8**: 271–276. *pls. 61–62.* 1903), in studying certain Mexican and Guatemalan species of Polypodium, has described 5 new species. — A. W. EVANS (Ottawa Nat. **17**: 13–24. *pls. 1–2.* 1903), in a paper on Yukon Hepaticae, embracing 38 numbers, has raised to generic rank Mesoptychia, one of Lindberg's sections of Jungermannia, and more recently a subgenus of Lophosia. — E. L. GREENE (Leaflets **1**: 1–32. 1903) has published, as segregates from Aster, *Oclemena* (*A. acuminatus* and *A. nemoralis*), *Lasallea* (*A. sericeus* as type), and *Unamia* (*A. ptarmicoides*); has recognized *Kyrstenia* Necker (Eupatorium § Ageratina) as entitled to generic rank, transferring the numerous species involved and describing 9 new ones; has described as a new genus *Uncasia* (to include *Eupatorium perfoliatum* and its numerous allies); in discussing certain genera of Polygonaceae, has recognized the generic rank of *Bistorta*, transferring the species and describing 6 new ones, and of *Duravia* and *Persicaria*, describing 11 new species under the latter. — J. R. JOHNSTON (Proc. Amer. Acad. **39**: 279–292. 1903). has published a revision of the genus Flaveria, recognizing 15 species, 4 of which are described as new. — N. L. BRITTON and J. N. ROSE (Bull. N. Y. Bot. Gard. **3**: (no. 9), 1–45. 1903), in publishing "new or noteworthy North American Crassulaceae," have described as new genera *Oliverella*, *Clementsia*, *Villadia*, *Urbinia*, *Gormania*, *Dudleya*, *Altamiranoa*, *Stylophyllum*, *Hasseanthus*, and *Sedella*, besides 101 new species. — R. S. WILLIAMS (*idem* 104–134), in reporting on a collection of Bolivian mosses, has described 3 new genera (*Chrysoblastella*, *Teretidens*, *Aligrimmia*) and 29 new species. — W. B. HEMSLEY (Jour. Linn. Soc. London **35**: 517. 1903) has published a new genus of Cyrtandraceae (*Rhabdothamnopsis*) from China. — C. S. SARGENT (Trees and Shrubs, part III) has published new species Crataegus (6), Euonymus, Viburnum, Pinus (W. Indies), and a new Mexican genus (*Gryphocarpa*) of Compositae by Greenman. — A. A. HELLER (Muhlenbergia **1**: 31–46. 1904) has described new species of Scutellaria (2), Agastache, Stachys, Monardella (5), Veratrum, Holodiscus, Boisduvalia, Gilia, Pentstemon, and Orthocarpus. — P. HENNINGS (Hedwigia **42**: 307. 1903) has described a new genus (*Biatorellina*) of Patellariaceae, and one (*Squamotubera*) of Xylariaceae. — Three new species of Opuntia left in manuscript by the late DR. WEBER have just been published (Gard. Chronicle III. **35**: 34. 1904). — W. SUKSDORF (West Am. Scientist **14**: 31–33. 1903) has published three new species of Nemophila. — J. M. C.

A. A. LAWSON[27] has obtained some most interesting results from a study of *Sequoia sempervirens*, whose essential morphology has long been a desideratum.

[27] LAWSON, A. A., The gametophyte, archegonia, fertilization, and embryo of *Sequoia sempervirens*. Ann. Botany **18**: 1–28. *pls. 1–4.* 1904.

The reduction division preceding the formation of pollen mother-cells occurs during the first week in December. Pollination occurs during the first week of January, each microspore containing tube and generative nuclei, with no trace of prothallial cells. The microspores remain in the micropyle three or four weeks before further germination, when tubes are put forth and pass in various directions, some between the integument and nucellus, others directly into the nucellus. No branching of tubes was found, as reported by Shaw. At this time the division of the generative nucleus into stalk and body nuclei was observed, the latter becoming surrounded by a dense mass of cytoplasm invested by a membrane. The maturity of the body cell was obtained at various times between early in May to the middle of June. The spindle organized for the formation of the male cells was found, but no trace of an organ suggesting a blepharoplast could be observed.

Five or six megaspore mother-cells become differentiated rather deep in the nucellus, and each one divides twice (about March 1), but develops only two megaspores. The ten or twelve megaspores begin to germinate, but only two or three get beyond the first division and continue to elongate toward the chalaza, and one of these soon becomes dominant. Free nuclear division occurs in the two extremities of the embryo sac, and at the last division neighboring nuclei become connected by radiating fibrils, and cell plates are formed. The development of the endosperm takes about three months, archegonium initials appearing during the first week in June.

Numerous archegonium initials become differentiated deep in the micropylar region of the prothallium, the neck cells being forced toward the periphery of the endosperm by the elongation of the central cells. Two neck cells were observed, confirming Arnoldi, though occasionally four were formed. The nucleus representing the ventral canal cell was also observed, which, in the absence of a cell plate and on account of its ephemeral existence, may well have escaped the earlier observers. A remarkable feature in connection with the archegonia is that their necks are directed toward the nearest lying pollen tubes, which have taken up various positions before the archegonia are formed.

Fertilization is unique in the fact that only the male nucleus, with a very small amount of cytoplasm, leaves the tube and enters the archegonium, the denucleated male cell retaining its form in the pollen tube. In fusion the two chromatin masses form a common network, and the male and female constituents become indistinguishable. As a rule, the two male cells fertilize two neighboring archegonia. The development of the embryo is also a decided departure from the ordinary early stages observed in conifers, in that there is no free nuclear division. The first division of the egg nucleus results in two walled cells, so large that they almost fill the egg. Subsequent divisions result in a row of five large cells, the lowest of which gives rise to the embryo, and the next above to the suspensor. In the first spindle of the embryo the

chromosomes were estimated to be thirty-two in number, and in the endosperm enough was observed to indicate that the number was approximately sixteen.—J. M. C.

ORIGIN OF THE OVULE.—Paleobotanical evidence for the origin of the ovule is accumulating with remarkable rapidity. In discussing the ovules of the older gymnosperms, F. W. Oliver[28] has described some most significant structures. The two ordinary types of unassigned paleozoic seeds are called for convenience Radiospermae and Platyspermae, the former including radially symmetrical seeds, the latter flattened ones. The simplest form is known as Stephanospermum (a radiosperm), in which the nucellus stands up freely within the integument: the apex of the nucellus is occupied by an extensive pollen-chamber; and "the chalazal strand of tracheids expands at the base of the nucellus into a tracheal plate, the margins of which are continued in the wall of the nucellus right up to the pollen chamber, the floor of which is paved with tracheids." The pollen grains are multicellular, and apparently liberated free-swimming sperms. The tracheal mantle of the nucellus is thought to be a mechanism for bringing water to the pollen-chamber, to be of use to the swimming sperms. This promiscuous liberation of swimming sperms is thought to be reminiscent of a heterosporous pteridophyte.

Among the platysperms (Cardiocarpus as type) there is the same tracheal plate at the base of the nucellus, from which tracheal strands extend into the walls of the nucellus at least as far as the separation of integument and nucellus. In this case the tracheal mantle, so far as known, is not so complete as in Stephanospermum. Moreover, the pollen grains are multicellular, but the cell-group by no means fills the entire grain. It is evident that the platysperms approach the cycads much more nearly in these particulars than do the radiosperms.

One of the most striking seeds, however, is that of Lagenostoma, from the lower Coal Measures. The integument and nucellus are free from one another only in the region of the pollen chamber, from the floor of which a conical mass of nucellar tissue rises, plugging up the micropyle (a structure, by the way, resembling that described by Hirase in Ginkgo), leaving the cavity of the pollen chamber a circular crevice. Surrounding the pollen chamber is the very complicated integument, consisting of an outer zone of heavy tissue, and an inner zone of large chambers separated by strong radiating plates. The internal angle of each chamber is convex, the inner wall of the integument thus forming a fluted membrane known as the "canopy." It seems that each of the large, vertical chambers of the integument was occupied by soft parenchyma, through which there ran longitudinally a single tracheal strand. In this case, also, the pollen grains were filled with tissue, indicating free-swimming sperms, and the more or less complete tracheal mantle would

[28] OLIVER, F. W., The ovules of the older gymnosperms. Ann. Botany **17**: 451–476. *pl. 24.* 1903.

represent the essentials of a contrivance for supplying the pollen chamber with water. The unique thing in Lagenostoma, however, is the peculiarly chambered integument.

Professor Oliver also calls attention to the general resemblance of modern cycads in the features described for radiosperms and platysperms, the main difference being found in the fact that only at the apex are nucellus and integument free from one another. Moreover, he describes the distribution of the vascular system in the cycadean ovule as probably derived from the vascular mantle found in the paleozoic seeds. He accounts for these differences, and also for the fact that among the cycads the integument and nucellus are distinct only at apex, while among the paleozoic seeds they are distinct to the base of the ovule or nearly so, by assuming that between the original ovule and its insertion a new region has been intercalated, resulting in a retreat of the nucellar bundles from the pollen chamber.

The remarkable case of Torreya is also introduced, whose anatomy suggests that it is the most archaic of living conifers, fuller details of which we are promised in a forthcoming memoir. Strong tracheal branches extend upwards from the tracheal plate at the base of the nucellus, and ultimately send branches into the nucellus which connect with a peculiar mucilage layer that may be a modification of the palaezoic tracheal mantle. It will be remembered that the other conifers have lost their nucellar vascular systems.

About the time the preceding paper was going through the press, Mr. Oliver and D. H. Scott[29] made preliminary announcement that the peculiar seeds of Lagenostoma, described above, belong to the genus Lyginodendron, one of the Cycadofilices of Potonié. The evidence for the intermediate position of this group has been drawn entirely from anatomical vegetative characters, and the discovery of fructifications was looked forward to with peculiar interest. An undescribed species of Lagenostoma showed young seeds inclosed in a husk or cupule, whose peculiar glands and whose internal anatomical structure were only duplicated in the vegetative organs of Lyginodendron. This genus, therefore, in its vegetative structure retains the intermediate position already assigned to it, but had fully attained the seed-habit.

On January 21, 1904, the same authors[30] presented their full paper to the Royal Society, and in connection with a discussion of the systematic position of Lyginodendron proposed the establishment of a distinct class, under the name *Pteridospermae*, to "embrace those paleozoic plants with the habit and much of the internal organization of ferns, which were reproduced by means of seeds." The opinion was ventured that not only Lyginodendrae but

[29] OLIVER, F. W., and SCOTT, D. H., On *Lagenostoma Lomaxi*, the seed of Lyginodendron. Ann. Botany **17**: 625–629. 1903.

[30] OLIVER, F. W., and SCOTT, D. H., On the structure of the paleozoic seed *Lagenostoma Lomaxi*, with a statement of the evidence upon which it is referred to Lyginodendron. Abstract preprint.

also Medullosae would be removed from Cycadofilices and included among Pteridospermae.

And now, in a note issued January 27, Professor Oliver[31] announces the discovery of three specimens of fragments of fronds of *Neuropteris heterophylla*, each bearing a large seed. As this Neuropteris is without doubt the foliage of a Medullosa, the two families Lyginodendrae and Medullosae, as prophesied, at present represent the known forms of Pteridospermae. While the new group is distinctly intermediate between Filicales and Gymnospermae, the undoubted seeds would include it among gymnosperms as at present constituted, although the form of the name would indicate the intention of proposing it as a third group of seed-plants.

Associated with the above results is a recent contribution by Miss Margaret Benson[32], who supports the theory of the soral origin of the ovule, and proposes an entirely new theory of the phylogeny of the inner integument. She finds that certain digitate clusters found among paleozoic plant remains are synangia that have dehisced septicidally and then opened along the ventral sutures for the liberation of spores. Telangium is a form-genus proposed to include such forms as were studied, and proofs are advanced to show that it is the microsporangial sorus of Lyginodendron. If this be true, the information concerning Lyginodendron has developed rapidly, and its intermediate character would be still further emphasized by the possession of a distinct ovule (Lagenostoma) and a microsporangial synangium (Telangium). In our own observation this is exactly paralleled by the case of Cycadoidea in which ovules are associated with synangia.[33] The most far-reaching suggestions of the paper, however, have to do with the origin of the ovule and the nature of the inner integument. The conclusion that the microsporangium of Lyginodendron is a synangium suggested that the megasporangium (Lagenostoma) of the same form might be derived from a synangium whose sterile sporangia are still represented by the anomalous cavities of the integument surrounding the functional sporangium, as described above. This interpretation of the "canopy" of Lagenostoma is supported by a number of arguments, including such analogies as may be obtained from the megasporangial sorus of Azolla, and the sterilized sporangia in the tufted sori of Botryopteris. This means that the ovule is a synangium in which the peripheral sporangia are sterilized and specialized as an inner integument! — J. M. C.

[31] OLIVER, F. W., A new pteridosperm. New Phytologist **4**: 32. 1904.

[32] BENSON, MARGARET, *Telangium Scotti*, a new species of Telangium (Calymmatotheca) showing structure. Ann. Botany **18**: 161–177. *pl. 11*. 1904.

[33] See COULTER and CHAMBERLAIN, Morphology of Spermatophytes. Part I. Gymnosperms. pp. 145–148.

NEWS.

A STATE forestry association has been formed in Vermont.

THE DEATH of Professor Wilhelm Behrens, of Göttingen, has just been announced.

PROFESSOR GASTON BONNIER has been elected president of the Botanical Society of France.

W. ARNOLD has been appointed professor in the University of Charkow and director of the botanic garden.

PROFESSOR H. DE VRIES and R. von Wettstein have been elected honorary members of the Berlin Botanical Society.

SCIENCE announces the death of M. Jean Dufour, professor of plant physiology at Lausanne, at the age of forty-three years.

THE UNIVERSITY OF MICHIGAN has received from Mr. J. B. Whittier, of Saginaw, $4,000 for the endowment of a fellowship in botany, named in honor of his mother.

DR. WILLIAM C. STURGIS, formerly mycologist of the Connecticut Agricultural Experiment Station, has been appointed lecturer in botany at Colorado College, Colorado Springs.

THE VERMONT BOTANICAL CLUB held its ninth annual winter meeting on Thursday and Friday, January 21 and 22, at the Williams Science Building of the University of Vermont.

PROFESSOR FRANCIS RAMALEY, of the University of Colorado, reached Tokyo, Japan, about the middle of January. He will visit Java, Penang, and Peradeniya, and will return *via* Europe.

DR. HARRY N. WHITFORD left the University of Chicago February 20 for the Philippine Islands, under appointment for two years as botanical collector in the government laboratory at Manila.

MR. R. H. YAPP, of Cambridge, England, known for his studies of myrmecophilous ferns, has been appointed professor of botany in the University College of Aberystwyth in succession to Professor J. H. Salter.

DR. H. C. COWLES, of the University of Chicago, has been sent by the department of botany to investigate the everglade region of Florida, using the U. S. Subtropical Laboratory at Miami as a base of operations.

DR. BRADLEY M. DAVIS, of the University of Chicago, sailed for Europe about January 1, to be absent from the university nine months. During the spring he will occupy a Carnegie table at the Zoological Station, Naples.

DR. CHARLES J. CHAMBERLAIN, of the University of Chicago, will visit Mexico in March under a grant from the Botanical Society of America to procure living and morphological material of certain endemic Mexican cycads.

PROFESSOR FRANCIS E. LLOYD, of Teachers College, New York city, has received a grant from the Botanical Society of America to study certain problems regarding the transpiration of xerophytes at the Desert Botanical Laboratory at the Carnegie Institution.

DR. E. W. OLIVE, who has been working on nuclear division in Cyanophyceae during the last year under a Carnegie grant at Bonn, is to continue his work under a new grant at the University of Wisconsin in the laboratory of Professor R. A. Harper.

THE STATION for Experimental Evolution, established by the Carnegie Institution at Cold Spring Harbor under the directorship of Professor C. B. Davenport, has secured the services of Mr. George H. Shull, of the University of Chicago, to conduct the work in plant-breeding and the study of mutations in nature.

THE FORESTRY department of the University of Michigan has been provided with an eighty-acre tract just outside Ann Arbor which is to be used for an arboretum of forest trees suitable for the state, model plantations of forest trees, and for demonstration and experiment plats. The land is the gift of Mr. Arthur Hill, of Saginaw.

THE RECENT DEATH of M. Émile Bescherelle interrupted the preparation of a useful work, a *Sylloge* of all the species of mosses described by him. M. Jules Cardot, to whom its completion was entrusted, writes that it will contain 450 to 500 pages, and that it will need to be published by subscription. It will be possible to print the work at $3 a copy, provided at least fifty of the minimum of 140 subscribers necessary to begin the printing can be found in the United States. Professor John M. Holzinger, of Winona, Minn., will receive names of subscribers.

A SOCIETY of more than usual promise has been founded in Germany, on the initiative of Dr. Engler, the "Vereinigung der systematischen Botaniker und Pflanzengeographer." Their first report, containing an account of the Berlin meeting last autumn is at hand. The purpose of the new organization is largely the systematic and unified exploitation of German taxonomy and phytogeography. The social factor also is concerned in the large response to Dr. Engler's call. Among the schemes which the society hopes to further is the preservation of typical natural plant formations. The next meeting is to be at Stuttgart, August 4–7, 1904.